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Views and Understandings of an Exemplary Secondary Science Teacher using Inquiry Instruction: A Case Study in England

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ABSTRACT

Inquiry instruction improves student learning, yet in the USA robust research shows secondary science teachers struggle to grasp inquiry. In 2015, academies are urging American teachers to come to a clear understanding of inquiry as a new framework gets adopted in the USA. Notably, this framework is akin to the National Curriculum in England, a country in which inquiry has received little attention. I use this opportunity to design a pilot study, and an instrumental case study, in England to illustrate the views and understandings of one exemplary secondary science teacher on inquiry as well as on factors influencing inquiry teaching. I draw on data sources—interviews, observations, vignettes, and artefacts—collected over a period of three months. I use inductive analysis to suggest five themes: (1) inquiry is an independent activity for students; (2) inquiry is a way to explore a topic and reveal misconceptions for teachers; (3) student knowledge and behaviour promotes inquiry; (4) absence of school resources constrains inquiry; and (5) a drive to show measurable attainment constrains inquiry. I find the teacher sharing rich inquiry activities and suggesting inquiry might have layers of independence and complexity. This empirical work could also have relevance to USA teachers in presenting a perspective on inquiry for preparing students. From my findings, I shape fresh ideas for teachers. I close by lending insight on considering a shared understanding of inquiry and directions for future research.

Key words:
Inquiry Instruction, Secondary Science, Case Study, Empirical, Student Learning.

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LIST OF ABBREVIATIONS

A-Level	Advanced Level
AQA	Assessment and Qualifications Alliance
Council	The National Research Council
DNA	Deoxyribonucleic Acid
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
OCR	Oxford Cambridge RSA
Ofsted	Office for Standards in Education, Children’s Services and Skills
PGCE	Postgraduate Certification in Education
USA	The United States of America

1. INTRODUCTION

This thesis reports a study in England with the aim of gaining fresh perspectives on inquiry instruction for secondary science teachers in the USA. Based on a period of three months, the research offers insight into the views, understandings, and reflections on inquiry with a skilled teacher practicing inquiry. Importantly, the aim of this study is not to generalise about teachers' views on, and practice in, inquiry or to rashly transfer ideas from England; instead, the research plans to capture in-depth knowledge from the skilled teacher, so American teachers may consider new ideas as they make clear the meaning of inquiry at the time that they adopt a novel framework, similar to the National Curriculum in England.

1.1. Research Aims

Walk into a science class in the USA and you will typically see a teacher lecture. The teacher talks; a student takes notes. In essence, this is passive learning. Another way to teach is through inquiry, which aims for active learning. Inquiry instruction gives students a chance to engage in science-based activities and skills, such as posing questions, conducting investigations, and communicating findings (Crawford, 2014). Today, inquiry is seen as a priority for secondary science teaching to improve student learning (Corcoran and Silander, 2009; Penuel, Harris, and DeBarger, 2015).

For the past few years, I journeyed to American schools to observe secondary science teachers practice inquiry. As a research assistant, I used a protocol to collect information on views, understandings, and practices and after class I asked teachers about inquiry instruction. My team studied teachers across the state of Rhode Island and, over time, we learned these bright instructors yearned to improve student learning. But we also noticed teachers mired in difficulties. Teachers were confused over the meaning of inquiry. Once we finished observing, my team published a report and we moved onto new endeavours. In the spring of 2014, I chose to teach professionally and was excited to instruct secondary science students using inquiry. Yet, I struggled with inquiry and succumbed to lecturing students.

During this time, what has surprised me most is the problem repeating across the USA. Large-scale work and consensus amongst scholars stress that teachers throughout the states have the same difficulties with describing and using inquiry instruction (Capps and Crawford, 2013; Osborne, 2014). Clear views and understandings are crucial to practice inquiry (Crawford, 2014; Prawat, 1992). If science teachers have a weak grasp of inquiry, they may fail to use inquiry (Crawford, 2007). Inevitably, this may not only impact student learning, but also job opportunities as labour markets and professional schools increasingly demand inquiry skills (Bybee, 2010; Schwartzstein, 2013; Stecher and Hamilton, 2014). This gap in understanding merits attention.

In the USA, institutes are seeking ways to come to a shared interpretation of inquiry. Notably, the National Research Council (2015) published a guide urging American teachers to create a common understanding of inquiry. This charge comes at a time when states are adopting a new framework to transform instruction and curriculum (Bybee, 2014; Pruitt, 2014). As states embrace the framework, and teachers set up talks to clarify inquiry, officials are calling upon American researchers to pursue innovative ways to solve problems with curriculum and instruction (National Research Council, 2012). I view this as an opportunity to study inquiry instruction in England to inform the discourse for American teachers and researchers as they convene to clarify inquiry.

An investigation in England is a fresh way to suggest ideas to teachers in the USA for several reasons. Though secondary science schemes may be unique, England and the USA share a mission to foster inquiry (Department for Education, 2012). Both nations also aspire for similar goals in their science curriculum (Jenkins, 2013). Alongside this, England employs the National Curriculum, which is parallel to a framework the USA is looking to implement for the next decade (National Research Council, 2015). With an absence of in-depth work done to date in England, I find this a timely occasion to study inquiry views, understandings, and factors that promote and constrain the use of inquiry, to offer novel perspectives for USA teachers.

1.2. Structure of the Thesis

This paper analyses the views, understandings, and factors promoting and constraining inquiry instruction of one secondary science teacher, who is skilled in using inquiry in England. First, I present a review of the literature on inquiry instruction and explain the definition, and current knowledge of inquiry for both countries, as well as the issues of considering fresh perspectives from one nation for another. This leads to the research questions. In the next two chapters, I describe the methodology of designing an instrumental case study and the methods of data collection and analysis. Then, I reflect on the ethical considerations taken in carrying out this work. Finally, I unravel the findings. I trace these results back to the literature to discuss the work and conclude by expressing the implications of findings for USA secondary science teachers and, more broadly, for future teachers and researchers.

2. LITERATURE REVIEW

This chapter turns to a review of the literature on inquiry instruction. It begins by describing definitions of inquiry instruction. The next section presents studies on views, understandings, and factors that promote and constrain the use of inquiry in the USA; next, these elements are reviewed in England. I then reflect on the role of considering ideas from England. This chapter ends with research questions.

2.1. What is Inquiry Instruction?

To date, there is a lack of shared understanding of inquiry instruction in science education (Crawford, 2014; Osborne, 2014). Whilst the aim of this paper is to gain insights on inquiry, I start this chapter by tracing the vast body of work that has sought to define inquiry. I close by noting the definitions and classifications used in this literature review to aid the interpretation of research in the USA and England.

Scholars have written widely about inquiry instruction and, over time, this has led to changes in the way the field views inquiry. In the nineteenth-century, English scientist Herbert Spencer implicitly described inquiry as teachers giving students a chance to investigate, through observation and experimentation, so students may see cause-and-effect relationships and improve reasoning skills (Spencer, 1861). Then, American academics expanded this concept. John Dewey said inquiry calls for teachers to support students as they engage in investigations—which includes finding a problem, forming a hypothesis, experimenting, and communicating findings—so students learn by reflective thinking (Dewey, 1910/1933). Reflective thinking includes students disciplined in growing personally, working with others, and engaging in meaning-making processes (C. Rodgers, 2002). Building on this work, Joseph Schwab refined the meaning of inquiry. Schwab classified inquiry instruction based on the responsibilities taken by the teacher and the student when carrying out investigations. In particular, inquiry considers two things: the person who poses the question, and the person who offers techniques and approaches to conduct the investigation. In this way, inquiry is either structured, in which the teacher takes full responsibility for posing a question and offering the approach for investigation, guided, where the teacher takes responsibility by posing the question, or open, in which the students takes full responsibility for posing a question and offering the approach for investigation (Schwab, 1962). This is illustrated in *Table 2.1*.

Table 2.1. Type of Inquiry Instruction by Responsibility

Type of Inquiry	Description
Structured	The teacher takes on full responsibility by posing a question, and then offering techniques and approaches for students to investigate the question.
Guided	The teacher takes on some responsibility by posing a question, and then having students take responsibility for offering techniques and approaches to investigate the question.
Open	The student takes on full responsibility by posing a question, and then offering techniques and approaches to investigate the question.

Source: Adapted from Crawford, 2014, p. 522; and, Schwab, 1960, 1962.

The end of the twentieth-century saw another shift in inquiry. Teachers raised concerns over the interpretation of inquiry (Welch, Klopfer, Aikenhead, and Robinson, 1981). Therefore, organisations led efforts to articulate and standardise the meaning of inquiry. A key institute was the National Research Council (1996), taking the step to express the goal of inquiry by gaining consensus from “large numbers of” science teachers and scientists over a period of more than 18 months in the USA (p. 14). *Table 2.2* presents the derived definition of scientific inquiry, including giving students a chance to engage in scientific activities to gain knowledge and understanding.

Table 2.2. A Definition of Scientific Inquiry by the National Research Council

Definition of Scientific Inquiry
The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

Source: National Research Council, 1996, p. 23.

Whilst the text above is wide-ranging, with eight activities and three requirements, the definition presents teachers with a positive starting point to think of the characteristics of scientific inquiry. Four years later, the Council advanced the concept of inquiry by publishing a guide to emphasise the importance of this type of instruction (National Research Council, 2000). Interestingly, in this work, the Council states that inquiry instruction varies by the direction that a teacher takes. However, they fail to define teacher direction; the Council notes only that teacher direction is fluid and contrasts with inquiry type—structured, guided, and open—as articulated by Joseph Schwab. This raises several questions. For instance, what describes teacher directions? When do teacher directions affect inquiry? And how would teacher directions influence inquiry? Alongside this, a lack of examples makes it difficult to picture directions a teacher might take whilst engaging in inquiry instruction. Still, the reference is useful in suggesting ways to prepare and support inquiry-based teaching using grids and instructional tools. This guide also sparked interest in building professional development programs to foster inquiry instruction.

Since the publication of the Council reports, much work[i] has shown that there remains confusion amongst secondary science teachers over inquiry. In the authoritative volume, *Handbook of Research on Science Education*, Osborne (2014), a senior researcher in secondary science education, voices concern with inquiry and the lack of shared understanding internationally amongst teaching professionals. Likewise, Crawford (2014), another senior investigator, conveys a similar stance with inquiry. In an effort to start the discourse on clarifying inquiry, she builds a working definition. She synthesises historical works from John Dewey, Joseph Schwab, and the reports from the National Research Council. With this, however, there is an absence of explanation of approach and criteria used to review works; such information may have given insight into the rigour of the synthesis. Nonetheless, Dr Crawford describes inquiry instruction and the components associated with it. On the next page, *Table 2.3* describes this definition of inquiry instruction.

[i] Empirical works are presented in the following sections of this chapter.

Table 2.3. A Working Definition of Inquiry Instruction by Dr Barbara Crawford

Working Definition of Inquiry Instruction
Teaching science as inquiry involves engaging students in using critical thinking skills, which includes asking questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models, and communicating findings in the pursuit of deepening their understanding by using logic and evidence about the natural world.

Source: Crawford, 2014, p. 515.

In the Crawford (2014) definition of inquiry, a teacher engages students to foster critical thinking skills and deepen understanding of the natural world. Interestingly, this description is similar to the National Research Council (1996) definition with the points of questioning, investigating, and communicating. But there are also differences. Compared to the Council definition, Crawford (2014) omits the term ‘activities’. She seems to supplant the term ‘skills’ with ‘activities’. Along with that, she removes several details, including making observations, examining books, and reviewing what is known given the evidence.

I close this section to note that, for the next parts of the literature review, I employ both definitions written by Barbara Crawford and the National Research Council. I also use the inquiry typology stated by Joseph Schwab, to examine the studies on views and understandings of teachers.

2.2. Views and Understandings in the USA

In this section, I start by specifying the methodology used to conduct the review. This is to capture the research on views and understandings of secondary science teachers on inquiry instruction, as well as on factors influencing inquiry. Then, I shift to examine these studies in the USA.

To begin this literature review, I employed a systematic approach. Publications were searched using three databases: Education Resources Information Center (ERIC), Google Scholar, and Web of Science. By using multiple databases, I aimed to reduce the risk of bias in excluding studies (Steinbrook, 2006). I carried out the search by reviewing English language papers published between 1 January 1996 and 1 May 2015. I chose this parameter since the push for inquiry research starts—not only in the USA but around the world—after the publication of the National Research Council (1996) book, "National Science Education Standards"; this period would also reflect present research rather than historical works in which the concept of inquiry may have been different (Abd-El-Khalick *et al*., 2004). Search queries included: 'inquiry', 'enquiry', 'inquiry instruction', 'enquiry instruction', 'science inquiry', 'science enquiry', 'secondary science', 'high school science', 'views', 'understandings', 'factors', 'promote', 'constrain', 'USA', and 'England'. To be thorough, I also examined non peer-reviewed or grey literature that may have missed works from searches using the databases noted above. I drew on Google Search for this strategy; this was important, since peer-reviewed studies to date on inquiry are limited in England. Overall, this yielded eight papers. For this literature review, I screened each piece to determine its focus. I also classified the papers by type of methodology and then analysed the study design and conclusions. For the papers cited in essay 1, I reread each piece and raised substantively different critiques.

Several USA studies have examined the views and understandings of secondary science teachers on inquiry. The following review organises studies by the two types of teachers, that is, novice and exemplary. I start by examining two studies concentrating on novice teachers and, then, two investigations focusing on 'exemplary'[ii] teachers.

In early work, Crawford (2007) studied the developing views[iii] of five novice secondary science teachers in a yearlong mentorship program in the eastern part of the USA. Through a multiple case study design, the investigator writes teachers were 'hand-selected' by mentors. Interestingly, there is an absence in rationale for this. One might infer convenience sampling and, in this way, selection bias may have been introduced. This could weaken the generalisability of findings to the intended population of novice teachers. The author also mentions that mentors were experienced and knowledgeable with inquiry. Yet, this claim is unjustified. The author simply adds: "such [mentor] teachers are difficult to find" (Crawford, 2007, p. 619); evidence of this may have added credibility. With data collection, the author considers several sources, including semi-structured interviews and a journal that

[ii] Of note, the two studies use the word exemplary in different ways; I critique this for both works.
[iii] Views are defined as "the interplay of teachers' knowledge and beliefs" (Crawford, 2007, p. 617).

notes information on conversations, meetings, and observations. This is useful to corroborate findings for internal validity. For data analysis, the author claims to use an inductive approach. With the interview, a coding methodology is described. With classroom observations, the author simply notes that a rating scheme was used to classify levels of inquiry; if this is based on theory or established scheme, this might imply deductive analysis rather than inductive analysis.

Despite some drawbacks to the methodology, Crawford (2007) does suggest interesting results. A key finding is that each novice teacher espoused different views and understandings on inquiry. In particular, the five teachers varied in their views on inquiry based on a spectrum ranging from lecture-driven, in which the teacher talks and students take notes, to 'open' inquiry, in which students pose questions and offer approaches for investigation. Amongst teachers, there was a lack of consensus on what entails inquiry instruction. The author also notes each participant's personal views of science, their knowledge of science discipline (i.e. epistemology), and how science may change, influenced their perspective and practice of inquiry instruction. Interestingly, teachers with weak science knowledge struggled to understand inquiry instruction.

In contrast to the multiple case design, more recently, Ozel and Luft (2013) conducted a mixed-methods study to ask 44 novice secondary science teachers in the western part of the USA about their views on inquiry instruction. The investigators used purposive sampling to capture first-year teachers. However, there is an absence of information on the recruitment strategy; the investigators only write, "this study used data from 44 teachers" (Ozel and Luft, 2013, p. 310). For data collection, field notes, interviews, and classroom observations were captured. They conducted interviews at the beginning and the end of year. With the analysis, they used a deductive process to classify the views of teachers on inquiry. Using interview transcripts, they coded data and employed a rubric from the National Research Council (2000) to examine the use of features. However, because they used a rubric, they grouped all forms of repetitions and variations of features into one type. They fail to describe how frequently they saw such anomalies; this data may have offered in-depth knowledge of inquiry instruction. Along with interviews, they collected and analysed observations using a rubric tool to classify inquiry.

Unlike the multiple case study by Crawford (2007), the mixed-methods work by Ozel and Luft (2013) found novice teachers generally viewing inquiry as scientific questioning and giving priority to evidence. From a descriptive perspective, these two findings form parts of the definition from Crawford (2014) and the National Research Council (1996). In addition, with respect to type of inquiry, many of the teachers viewed inquiry as being 'structured'[iv] rather than 'guided' or 'open'.

In contrast to novice teachers, researchers have also studied exemplary teachers' views on inquiry in the USA. These investigations, however, use the term exemplary in different ways and I clarify this as I present the next two studies. Using a mixed-methods design, Breslyn and McGinnis (2012) examined the conceptual views, understandings, and practices of 60 exemplary secondary science teachers on inquiry instruction. The researchers define exemplary teachers as being nationally board certified and claim such teachers have a strong understanding of inquiry. To support this, they cite a technical report and a case study[v] examining the influence of board certification on inquiry understanding. These investigators assert previous quasi-experimental findings[vi] suggest credentialed teachers outperforming non-credentialed teachers on inquiry understanding (Lustick and Sykes, 2006). However, if one reads the technical report carefully, the evidence is weak to suggest board certified teachers have a strong understanding of inquiry. A key problem is with the assessment used for inquiry understanding. Specifically, from a face validity perspective, the technical report authors write the causal link:

- "Would be wrong, for example, to conclude that because there was a significant increase in the mean scores for *Scientific Inquiry* teachers are necessarily better at teaching with a scientific method or that they now know

[iv] The authors use the term 'directed'; this is defined as "the teacher provided the question and the mechanism for the student to answer a question" (Ozel and Luft, 2013, p. 311). This corresponds with the description of 'structured', written by Joseph Schwab, as noted at the start of this chapter.
[v] This is a case study of three secondary science teachers who are board certified (Park and Oliver, 2008); the findings state these teachers "became more aware of the importance of inquiry in science teaching" (p. 821), rather than gained understanding of inquiry. Given a small sample, it would also be problematic to generalise this work to the USA population of science teachers who are board certified.
[vi] The researchers used an assessment rubric to measure changes in a pre-test and post-test of inquiry understanding. Based on consensus from science teachers, researchers, and leaders, this assessment includes the standard of scientific inquiry, which focuses on "how scientists ask questions and seek answers through a form of systematic process [that] is vital to understanding the knowledge constructed, discovered, or investigated. Scientific inquiry is more than the scientific method, it also describes the pedagogy associated with open-ended investigations" (Lustick and Sykes, 2006, p. 78).

> more about teaching with scientific inquiry" (Lustick and Sykes, 2006, p. 160).

Here, I also draw attention to the technical report point that the assessment used in the quasi-experiment may be capturing inquiry behaviour rather than inquiry understanding (Kowalski *et al.*, 1997). In this way, the test may be failing to measure what it intends to measure—understanding of inquiry instruction—raising concerns with the Breslyn and McGinnis (2012) assumption that exemplary teachers, defined as board certified, have a strong understanding of inquiry.

Whilst the claim of board certification and inquiry understanding is tenuous, the Breslyn and McGinnis (2012) study is strong with recruitment strategy. The researchers used stratified random sampling to select 48 teachers from a national population of board certified teachers. Interestingly, a definition of population is absent. One may question whether the population is based on a robust database or a list the authors created. Details would have been useful for readers to judge how well the selection, indeed, may generalise to board certified teachers in the USA. Given this, the authors randomly select 12 different teachers the following year to conduct interviews. However, they fail to note whether these 12 teachers randomly identified had all initially consented to participate in the study, and if any refused or dropped out to participate. This data would help decide if selection bias played a role for interviews.

For data collection, there are strengths and weaknesses with the Breslyn and McGinnis (2012) study. They were able to capture 48 portfolios[vii] and carry out 12 interviews. The portfolios were standardised to include lesson plans, video segments, and reflections on inquiry. For strength, this uniform data could minimise the amount of missing information. Along with portfolios, they conducted semi-structured interviews to clarify the interpretation of the portfolios. However, teacher interviews were based on a cohort different from teacher portfolios studied. The investigators fail to justify this discrepancy.

[vii] In the USA, board certification is an advanced teaching credential; with this training, a portfolio is designed (National Board for Professional Teaching Standards, 2013). This type of portfolio is usually absent amongst the general population of USA teachers as they are non-board certified.

With portfolios, the authors approach analysis using two techniques. On the one hand, an inductive approach is used to analyse portfolio text to create themes on goals and enactment of inquiry. The authors developed codes from a pilot study; however, they omit details on how this informed coding. Aside from inductive analysis, they also use deductive analysis. Breslyn and McGinnis (2012) employ an inventory instrument to rate inquiry enactment, but fail to state how each part of the portfolio's lesson plans, video segments, and teacher reflections were analysed. Detailed analysis by parts would have added depth for readers on differences and similarities captured, and what the authors did with this when interpreting results. Finally, the authors mention analysis of 12 interviews. They state it was done in "a grounded theory fashion" (Breslyn and McGinnis, 2012, p. 59). Yet, they fail to describe this approach. There are different ways to frame this. For instance, some use this technique for validation purposes whilst others use it to generate ideas (Richards and Morse, 2013).

Given some limitations to the design, Breslyn and McGinnis (2012) do present interesting results. The authors note two key findings. First, science discipline tends to influence teachers' conceptual views of inquiry instruction. They discovered patterns in four disciplines. *Table 2.4* illustrates the views of participants on inquiry by discipline.

Table 2.4. Views of Majority of Certified Participants on Inquiry by Discipline

Discipline	Views
Biology	Teacher suggests question. Students given a chance to conduct science investigations.
Chemistry	Students offered an opportunity to acquire content knowledge.
Earth Science	Students given a chance to conduct science investigations.
Physics	Teacher presents problem. Students given a chance to grasp content knowledge and engage in modelling to generate equations and describe phenomena.

Source: Breslyn and McGinnis, 2012, pp. 60-69; the table adds details to the essay 1 work. Certified denotes National Board Certification in Secondary Science Education in the USA.

With the findings, Breslyn and McGinnis (2012) consider exceptions to the pattern—based on differences in curriculum and student ability—yet maintain that science discipline drives participants' views and enactment of inquiry instruction. Interestingly, when reflecting on the definitions of inquiry at the start of this chapter, the views from each discipline feature only two student activities (i.e. investigation and building models) of those cited by Crawford (2014) and the National Research Council (1996). Also, when considering the inquiry classification from Schwab (1962), Breslyn and McGinnis (2012) report only biology and physics teachers showing patterns in which the teacher takes responsibility for asking questions. The investigators, though, fail to note if the teacher or the student would then offer the techniques to investigate the question.

Along with considering teacher discipline, Breslyn and McGinnis (2012) suggest teachers who specialise in two or more science disciplines may hold flexible views on inquiry instruction. The investigators state that teachers' views on inquiry may adapt to the discipline they teach at that moment. Overall, considering the limitations on the study design, their research suggests that science discipline might influence the ways board-certified secondary science teachers view inquiry.

Recently, Capps and Crawford (2013) carried out a mixed-methods study with 26 outstanding secondary science teachers who taught exemplary inquiry lessons. To do this, the authors asked teachers about their views and practices of inquiry instruction. The researchers claim to select teachers with specific criteria: "outstanding credentials, willingness to participate in all aspects of the project, and evidence that their views on teaching were not in opposition to reform-based teaching", whilst instructing, "an exemplary, inquiry-based lesson" (Capps and Crawford, 2013, p. 504). However, the authors fail to describe each criterion. An explanation is critical to suggest that the criteria employed are, indeed, useful in selecting participants who taught exemplary inquiry lessons. To strengthen this claim, the authors could have defined outstanding and exemplary inquiry lessons. One might ask: is this based on judgment from the authors, and how are the qualified to make this decision? An absence of explanation might leave readers to question the credibility of selecting outstanding teachers who taught exemplary lessons.

Whilst internal validity may be questionable, Capps and Crawford (2013) use suitable methods to select teachers, and conduct data collection and analysis, for the investigation. The researchers employ purposive sampling to capture 30 teachers who fit their criteria. However, they state that complete information was gathered only for 26 teachers so they analysed data from this group. Details of the four teachers with incomplete data would have been informative to suggest if bias could have played a role, for instance, due to attrition or refusal to participate. With 26 teachers, the authors collect two source of information: classroom observation of several hours, and a lesson description of exemplary inquiry. To review lessons, a coding scheme from previous work was used to deductively analyse the presence of inquiry. They also found validated instruments to deductively analyse whether the teacher or students were responsible for initiating the lesson as well as the views of teachers on inquiry. Interestingly, amongst the 26 teachers, the researchers interviewed eight teachers since they lacked "robust ability" to demonstrate inquiry instruction (Capps and Crawford, 2013, p. 506). The authors suggest they use this to gain insight into practice; however, they omit defining "robust ability" with teaching inquiry. Clarity on the meaning would offer readers understanding of the strength and utility of the interviews.

Capps and Crawford (2013) shed light on three key findings. First, they assert most participants held uninformed views on inquiry. The investigators write that many participants confused inquiry instruction with hands-on teaching. Whilst this description is useful, there is an absence of explanation to critically judge that participants, indeed, were confused with inquiry instruction. For instance, it could have been that participants were using the phrase hands-on teaching to substitute as a type of inquiry or as another form of instruction, including cookbook investigations (McLaughlin and MacFadden, 2014). To support their claim, interviews with more teachers would have been useful to gain deep understanding.

Along with holding confused views, Capps and Crawford (2013) state teachers had a "conspicuous" lack of understanding inquiry (p. 509). The investigators present a figure illustrating no account of inquiry understanding across 26 teachers. Whilst striking, it also raises concerns. Importantly, there is a lack of critical interpretation of the findings. They fail to note alternative explanations, such as limitations of data collection instruments and analysis approaches used to synthesise participant understanding (King *et al.*, 1994). This description would have added balance to their discussion.

Finally, Capps and Crawford (2013) find variation in inquiry instruction practice. They point out a pattern: six of the 26 teachers practiced inquiry with questioning and data collection activities. Whilst descriptive, the investigators omit details on the 20 other teachers' practices; such data would have offered balance to note the types of instruction all teachers practiced. Overall, based on these results, the authors claim widespread confusion in the USA over inquiry instruction. Given the scant data collection, limited sample size, and lack of random sampling, however, this logic is somewhat weak for the purposes of generalising to teachers across the states. Nonetheless, the study does raise sobering questions over the ways these participants view, understand, and practice inquiry instruction.

This section presented a review of four studies. Each piece explained the views of secondary science teachers on inquiry in the USA. The two papers with novice teachers presented disparate views on inquiry; in the western part of the USA, though, investigators suggested teachers tended to understand inquiry as 'structured'. Then, the two research papers reporting exemplary teachers raised questions about the authors' capacity to capture such instructors. Whilst there were limitations to the link between exemplary and inquiry understanding, one study did suggest board certified teachers viewing inquiry based on their scientific discipline. The other study suggested teacher confusion over inquiry. Now, I extend this review to discuss factors that may promote and constrain inquiry.

2.3. Factors Promoting and Constraining Inquiry in the USA

In this section, I focus on factors influencing the use of inquiry in the USA. I review two case studies. In an early investigation, Roehrig and Luft (2004) designed a multiple case study with 14 novice secondary science teachers who were participating in an induction program "to foster inquiry-based environments" over a period of one year (p. 7). With this work, the focus was on asking teachers about constraints. The researchers recruited teachers who participated in an induction program. However, there is an absence of information on the total number of teachers participating in the program and the sampling approach taken. For data, the authors collected information from many sources, including artefacts, interviews, questionnaires, and classroom observations. With analysis, though, the authors fail to describe whether inductive or deductive approaches were used. Full explanation for each approach would have been instructive to judge the internal validity of the work.

Conscious of data collection strengths and analysis weaknesses, Roehrig and Luft (2004) offer some insights. First, they assert that interacting factors, rather than single factors, constrain the use of inquiry. Constraints include the interaction of three factors: teachers having weak content knowledge, viewing pupils unable to do inquiry, and understanding poorly the nature of science. Interestingly, the authors suggest the opposite—interaction of teachers with strong content knowledge, viewing pupils as able, and good grasp of the nature of science—would promote inquiry. The authors also rank these three factors. They mention teacher content knowledge as a top factor influencing inquiry, followed by teacher views of pupil ability and then teacher understanding of the nature of science. Given this ranking, though, the authors fail to justify this conclusion; to strengthen the claim, evidence from their analysis would have added rigour.

Along with interacting factors, in a different multiple case study design cited in the previous section, Crawford (2007) mentions that the five novice participants suggested time, curriculum rigidity, and student resistance as constraints to inquiry. In particular, curriculum standards discouraged teachers to pursue inquiry. Some teachers became concerned that spending time with inquiry would lead to incomplete objectives demanded by the curriculum. Other teachers cited students who engaged in investigations became concerned with uncertainty. Several teachers expressed student resistance to exploration; these teachers mentioned students wanting directions and expectations of results.

This section traced two studies that focused on factors that promote and constrain the use of inquiry. Whilst empirical studies were limited, authors suggest one key factor promoting inquiry: the interaction of strong content knowledge and good understanding of the nature of science as well as views of student ability to do inquiry. In contrast, curriculum rigidness and student pushback may constrain inquiry. This concludes the reviews in the USA. Now, I shift to emerging studies in England.

2.4. Views and Understandings in England

The last section shed light on factors influencing inquiry in the USA. To date, research on inquiry instruction is scant in England. Based on the literature search strategy, one published work from the government and two preliminary studies were reviewed. I present the work in order of publication. I begin by examining the large-scale government work and then focus on the preliminary studies launched in England to promote inquiry instruction.

Recently, the Office for Standards in Education, Children's Services and Skills (Ofsted) published a report called "Maintaining curiosity", which outlines the practices and understandings of secondary science teachers on inquiry[viii] (Ofsted, 2013). Whilst this comes from an inspection system, it lacks peer-review. Several scholars have suggested that the absence of information typically found in inspection reports raises questions on rigour and reliability of findings (Gaertner and Pant, 2011; Sinkinson and Jones, 2001). For instance, compared to papers found in research journals, inspection reports typically fail to have the results scrutinised by specialists to maintain validity standards. Given this, I interpret the findings.

Ofsted claims to have surveyed 89 secondary schools and observed 638 lessons in a period of three years. Whilst they note the numbers of schools and lessons observed, they fail to numerate teachers who were asked about inquiry instruction. This information would have been useful to gain insight into the generalisability of the findings to teachers in England. For sampling, Ofsted sets out to choose schools that are representative of several factors, including socio-economic condition, overall effectiveness, and student characteristic. Yet, they fail to give evidence to suggest that their sample had achieved representativeness. To strengthen the claim, Ofsted could have presented statistics to confirm that their sample was reflective of schools in England. For data collection, the report notes inspectors conducted observations as

[viii] Of note, the report writes 'enquiry'. The authors fail to define 'enquiry'; they also lack offering citations or references to explain inspectors' observation criteria of 'enquiry instruction'.

well as held discussions with school members, groups of students, and available governors. These inspectors also studied written works of science.

Interestingly, whilst Ofsted notes data collection, they fail to describe their analysis. A lack of explanation raises concerns about the nature of findings. In particular, one may question whether this analysis was done in systematic ways to strive for objectivity. If not, there could be bias in the findings. For example, if inspectors analysed some observations whilst neglected to analyse other observations, due to time constraints, then this may introduce problems in the representative nature of the findings.

Despite these shortcomings, Ofsted presents two key findings on inquiry. First, the inspectors suggest many secondary science teachers seem to use inquiry as a way "to teach the content, ideas and understanding that were needed, and they made students' independence and involvement in learning a priority" (Ofsted, 2013, p. 30). Ofsted also writes teachers would engage students to become scientists and go beyond the lesson. For both claims, one concern with internal validity is the approach taken by Ofsted. The inspectors support this with one source of evidence: observations. Ofsted fails to corroborate this information with other data like interviews with teachers or through data they collected from other sources. To enhance the credibility of findings, it would have been useful to collect from data sources, and compare and contrast the information.

Along with fostering student independence, Ofsted found teachers aimed to instruct investigative science. As part of the National Curriculum strand called How Science Works, Ofsted (2013) notes teachers engaged well with investigative science at an early stage level; but they became busy at Key Stage 4. Ofsted, though, fails to clarify if investigative science is part of inquiry instruction or if it is another type of instruction. This lack of depth makes it difficult to justify if many teachers understood investigative science to be inquiry. Overall, the Ofsted report suggests that many teachers viewed inquiry instruction as a way to teach and foster independent learning.

Concurrently with the inspection report, Engeln *et al*. (2013) published an article based on cross-sectional survey methodology. In 12 European countries, they study the views and understandings of secondary math and science teachers on inquiry. These teachers participated in a project that aims to foster inquiry teaching. For recruitment in the UK, the sample represented 71 secondary teachers around the area of Nottingham, England[ix]. The authors fail to mention random or purposive sampling; accordingly, this study could be using convenience sampling. To this end, there are limitations to the generalisability of findings to secondary teachers across England.

Given the sampling approach, Engeln *et al*. (2013) used an online questionnaire. This instrument was made of 32 items, focusing on the areas of inquiry, professional development, and current classroom practice. To develop this survey, the authors claim to extract items from past research; yet, they fail to note if their final instrument was piloted or validated. Information on this would have been useful to offer confidence that questions were sensible to the participants and measured areas the investigators aimed to measure.

Considering data from the questionnaire, Engeln *et al*. (2013) combined math and science teachers in England for convenience to present findings. As a disclaimer, the authors write, "considerable differences between the subjects do exist" (p. 827). In this way, I consider this work with caution since there is a conflation with findings from math and science teachers. The study suggests two findings for the teachers around Nottingham, England. First, participants viewed inquiry positively. Second, these participants consider inquiry instruction to be teacher-oriented. Teacher responsibility might suggest a form of 'guided or 'structured inquiry, based on the Schwab (1962) typology. In this way, the teacher may be responsible for posing a question and possibly offer the approach to conduct an investigation.

Most recently, Harrison (2014) published pilot findings on the views and understandings of 16 expert secondary science teachers on inquiry instruction as they participate in an inquiry project that produces materials for teachers so they may

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[ix] As briefed in essay 1, I emailed the study author. In response, I learned this project member comes from the Nottingham part of England (K. Maass, personal communication, November 26, 2014).

assess inquiry skills. Importantly, when compared to the two USA studies on exemplary teachers, Harrison (2014) fails to define 'expert' teachers. For recruitment, the author notes the participants were from the pilot program. However, there is an absence of information on sampling; information on the total number of teachers participating in the pilot may have added clarity on whether the authors strived for purposive or convenience and whether the sample selected, indeed, was representative of all the pilot teachers. The investigators also wrote that data collection is based on field notes taken at meetings. This is one data source. However, there is an absence of collecting other sources, such as artefacts and observations; this suggests a lack of triangulation. Alongside this, the authors omit noting the approach to analysis, which raises concerns of bias and interpretation of findings.

Given weaknesses in the data collection and absence of analysis methods, Harrison (2014) reports two findings. First, participants who became confident engaged in 'open' inquiry. Second, confident participants assessed several student skills, including teamwork, communication, and critical thinking. Mindful that this is pilot work, the findings suggest some confident teachers who are participating in this program may be using 'open' and assessing multiple types of skills.

In sum, this section presented three studies on the views and understandings of teachers on inquiry. The inspection report suggested the use of inquiry to foster independent learning and investigative research. Then, the survey work presented teachers viewing inquiry positively and teacher-oriented whilst the pilot study seemed to find confident teachers using 'open' inquiry and assessing student skills. In the next section, I focus on the factors influencing inquiry instruction in England.

2.5. Factors Promoting and Constraining Inquiry in England

This section picks up on the studies in England to review the research on factors influencing inquiry. Unlike the USA, to date there is an absence of research explicitly asking teachers about issues that promote and constrain inquiry. Though, the works from Ofsted (2013), Engeln *et al*. (2013), and Harrison (2014) do comment on factors and I synthesise the evidence for this section.

Ofsted (2013) reports two key factors promoting inquiry instruction. First, Ofsted suggests the best teachers reduce time pressure from coursework to promote inquiry. The inspectors also note such teachers resisting temptations to instruct all content; instead, they limit the breadth and carve out time to give students a chance to conduct practical work to explore science ideas. Interestingly, the report states, teachers who are 'best' had considered this factor; yet, Ofsted fails to define the characteristics of a best teacher. Along with the best teachers allocating time for inquiry, Ofsted notes that school leaders built in opportunities to foster student independence. Specifically, leaders designed a school mission to encourage independent learning and employability skills. Ofsted suggests the school initiatives led students to view inquiry skills as important for their careers.

Harrison (2014) notes another promoting factor: the teacher's use of formative assessment whilst students engage with inquiry work. The author suggests teachers who listen during class discussions may capture evidence of students' understandings. Through this, teachers may discover errors and misconceptions. As a result, teachers may scaffold students' understanding in future lessons. Whilst this explanation is offered, Harrison (2014) fails to offer examples to suggest formative assessment is useful.

Along with promoting factors, Ofsted (2013) and Engeln *et al*. (2013) write about constraints to inquiry instruction. Ofsted (2013) indicates that a key constraint for inquiry instruction is when teachers have little space for conducting laboratory-based practical work. Because of this, teachers and students have a reduced chance to engage in presenting new ideas during class discussions. Engeln *et al*. (2013) similarly notes that resources are a constraint; the authors add that systemic restrictions, for instance, coming from school systems, may pose a barrier to inquiry instruction. However, Engeln *et al*. (2013) fail to describe these two constraints.

This section reviewed three factors that promote and constrain inquiry in England. Factors that promote inquiry include allocating time in class, conducting a formative assessment by listening and discovering errors, and having leadership recognise the importance of independent work. Constraining factors were school restrictions and limited laboratory resources.

2.6. Carefulness in Considering Ideas from England for the USA

Up to this point, I have focused on inquiry and its relationship to views of secondary science teachers and the factors that influence inquiry instruction in the USA and England. In this section, I reflect on literature examining the approach taken to study ideas from one nation to considering for another. I start with the benefits, and I end with the perils of such work.

In education, one strand of scholars point out the benefits of studying one nation from the perspective of another. In particular, this work may help make familiar what is at first unfamiliar to refine understanding (Little, 2010). With respect to inquiry instruction, this argument justifies an attempt to gain perspective on the views of secondary science teachers in England. Through this, teachers in the USA may have the chance to think critically about differences and similarities as well as anticipate and prepare for unfamiliar situations. This argument supports the assertion that studying different perspectives, considering the culture and values of the nations, would be useful to "enhance our understanding of the interplay of education and culture and help us to improve the quality of educational provision" (Alexander, 2001, p. 521).

Another strand of academics note caution in bringing insights from foreign countries. Sadler (1900) explains researchers studying distant education systems need to grasp context. Yet, he suggests this may be impossible. For instance, differences in culture and politics may influence education schemes (Cohen, 2014). Recently, Brookings Institution Senior Fellow Tom Loveless articulates specific problems. He suggests three perils in studying foreign education systems. First, he reflects on research that singles out high performing countries in a particular area. Second, he questions the representativeness of the sample of such work for generalisabilty purposes. Finally, Loveless (2014) writes, cross-perspective work is commonly used to confirm prior expectations; in other words, such research acts out confirmation bias. I anticipated these issues in my study design and address them below.

As cited in the introduction, I chose to investigate in England for several reasons. Broadly, England has similar values and interests as the USA in promoting inquiry instruction (Department for Education, 2012). Then, in response to Loveless's first peril of studying high achievers, the research is framed in England since it is close in secondary science student performance[x] to the USA. One proxy of` comparative performance commonly used by educational researchers is the Programme for International Student Assessment (PISA). In 2012, a sample of 15-year-old students took the assessment in 64 countries and, given sampling error and measurement error, students in England performed somewhat better in science than students in the USA; neither country, though, were top achieving outliers (Department for Education, 2014b).

With respect to Loveless's claim to representativeness of the sample: if one intended to generalise to the population of secondary science teachers skilled in using inquiry in England, this would be fundamentally important. Yet, my study is strictly intended for in-depth understanding of using inquiry rather than generalising findings to the country of England. As evident in the literature review, there is an absence of shared understanding amongst teachers on inquiry. I believe an exploratory approach is useful since comparative work suggests "informed research into aspects of education 'elsewhere' can provide a proxy for what might result from reform 'at home', without the risk attached to an experiment with such otherwise untested reform" (Phillips, 2006, p. 556). In other words, instead of thinking about strict transferability, an investigation may be fruitful for considering ideas.

Reflecting on both strands of scholars, I am mindful of considering ideas from one nation for another. Such work requires meticulous attention due to national differences, with respect to culture and politics. Overall, the previous sections focused on the literature of inquiry. In the next section, I enrich this discussion by turning to the research questions.

[x] In particular, I acknowledge student learning is difficult to measure (Koretz, 2008); it is highly complex to compare student learning across nations.

2.7. Research Questions

Much work has been done in the USA with novice and exemplary secondary science teachers showing a disparity in views on inquiry. In England, some work has been done; but there are key limitations with these studies. Along with internal validity problems[xi]—based on data collected from inspection observations, online questionnaires, and pilot project field notes—the findings are insensitive to the perspective of the individual for the purposes of advancing knowledge (Taylor, 2014). What is missing is in-depth understanding of inquiry. In England, asking a skilled secondary science teacher of inquiry over a period of time would be a novel way to deeply study not only views on inquiry but also factors that influence the use of inquiry. I venture in this direction to ask two questions:

I. What are the views and understandings of an exemplary secondary science teacher on inquiry instruction in England?

II. How does an exemplary secondary science teacher reflect on factors that promote and constrain the use of inquiry in England?

[xi] In the literature review sections of England, I raise concerns of the absence of data triangulation and lack of analysis information in the inspection study (Ofsted, 2013). There is also missing information about the teachers studied in the emerging studies (Engeln *et al*., 2013; Harrison, 2014).

3. METHODOLOGY

This chapter extends the write-up on the literature review and research questions. I shed light on the methodology to conduct the study. The chapter begins with a rationale for choosing an instrumental case study. It then turns to the sampling procedures to select the teachers for the pilot and formal investigation.

3.1. Instrumental Case Study Design

I start this section with a rationale for creating a case study. Then, I note the philosophical and constructivist underpinnings of this work. I close with a discussion on delimiting the scope of this study.

As briefed in the literature review, to date research in England has asked typical secondary science teachers about inquiry instruction. However, there is an absence of investigation asking teachers who are skilled and knowledgeable with inquiry. In this way, I look for the atypical teacher to "reveal more information because they activate more actors and more basic mechanisms in the situation studied" (Flyvbjerg, 2013, p. 181). Information gleaned from the atypical teacher may also prompt actors—prospective and future teachers and researchers—to critically reflect on inquiry from the skilled teacher and offer fresh perspectives for teachers in the USA.

There are several ways to study an atypical teacher. Creswell (2013) suggests narrative research, phenomenology, and case study. Whilst narrative work offers an interesting way to collect stories of the individual, this approach may fail to demonstrate an in-depth analysis of inquiry instruction, which is an aim for my research. Narrative work also poses a challenge since it relies on the investigator, myself, to have an acute understanding of the teacher's life; as an outsider from the USA, with limited time in England, this would be problematic. Phenomenology is another research design to promote the understanding of the teachers' lived experience as they practice inquiry. With this, I could capture 'what' and 'how' a teacher experiences practicing inquiry. But a phenomenology approach lacks the ability to engage with the goals of deep understanding since, to be robust, phenomenology commands more than three teachers who have experienced practising inquiry in common to gain holistic views and understandings of inquiry. This would be logistically difficult to design; by definition, when compared to the number of general or typical teachers in England, the number of teachers who are skilled and knowledgeable in inquiry is expected to be small. Instead, I draw on selecting one skilled and knowledgeable teacher as a case to best understand the issue of inquiry instruction. In this way:

- "[The] particular case is examined mainly to provide insight into an issue… the case is of secondary interest, it plays a supportive role, and it facilitates our understanding of something else" (Stake, 2005, p. 445).

Given this, the 'particular' refers to the secondary science teacher skilled and knowledgeable in using inquiry—or atypical teacher—in England. The 'something else' links to the larger issue of inquiry instruction with respect to the two research questions, which include the views and understandings on inquiry instruction as well as reflection on factors that promote and constrain the use of inquiry. This methodology is called an instrumental case study. Unlike research looking at particular circumstances of the atypical teacher, considered an intrinsic case study, or striving at generalising to a population of atypical teachers, deemed collective case study[xii] (Stake, 2005), my intent is to employ an instrumental case study so that the atypical teacher plays a supportive role to share insights into inquiry instruction.

Philosophically, from an ontological perspective, this research orients toward the reality that views and understandings of a skilled teacher are observable in the world. Through an epistemological stance, or 'how one knows this', I consider this knowledge attainable through talking with and observing the teacher. And considering axiology, that is, my values that may drive actions and judgments, I deem rich interaction with the teacher in England may support the construction of this knowledge. I believe multiple realities exist with this teacher; in this way, rather than frame this research as a positivist paradigm, to claim there is an objective truth, I take

[xii] In theory, a qualitative study with multiple atypical teachers could be conducted. However, this type of investigation is difficult to carry out from a sampling and recruitment perspective given limited time of a few months and a small number of atypical teachers available; I explain this in the Sampling.

the stance that knowledge is socially constructed. In this case study, I use a constructivist research model to capture the meaning of the participant's views and understandings on inquiry.

Using a constructivist paradigm to the teacher, to add focus, I draw boundaries to the instrumental case study by marking a fixed time period and grade level that the teacher would instruct. I pay attention to boundaries not only to add scope for data gathering, but also to inform future researchers who may seek operational definitions for guidance on constructing such work (Yin, 2014). In particular, I choose the period of three months as this gives me the greatest feasible time in my studies for data collection, analysis, and response validation. Another part of the boundary is grade level; rather than focus on lower grades, I choose Key Stage 4 and above since this is when students would have the greatest opportunity to engage in scientific activities, which is at the heart of inquiry (Department for Education, 2014a). With this delimitation, my goal is to gain rich understanding of inquiry instruction by studying one skilled secondary science teacher in England.

3.2. Critique of the Single Case Study Design

The previous section constructed a rationale for designing an instrumental case study. Now, I reflect on concerns in conducting such work with one participant in the formal study. This section ends with a suggestion of benefits for teachers in the USA.

Scholars may raise questions about studying a single case for several reasons. This concern, in part, may stem from applying the semantic of statisticians (Small, 2009). Morgan and Morgan (2009) write, "we tend naturally to be distrustful of small numbers, and so we might logically question whether the results… would have any bearing" (p. 11). Yet, sample size is pivotal for external validity and generalisability purposes, if one aims to make claims about the population, such as secondary science teachers skilled in inquiry in England. I designed the study to gain in-depth understanding of the particular instead of generalising to the entire group of teachers. This is because I aim to study an atypical case: the exemplary teacher skilled in inquiry instruction. In my single case study design, the purpose is to explain and examine the case. With this, I avoid seeing this single case as "part of a survey sample" whose purpose is to represent all secondary science teachers skilled in inquiry in England in order to construct fundamental knowledge (Denscombe, 2014, p. 83).

Alongside this, by selecting a single atypical case, I expect there to be peculiarities to the single case design, just as researchers would suspect peculiarities to studies involving multiple cases no matter how well-designed they are for producing ideas (Ragin, 1992). With the atypical case, the peculiarities are an asset because the point is to expand interpretation as "the outlier is prized, for the outlier has the greatest heuristic value" (Donmoyer, 2009, p. 63). Importantly, new variables may be identified. In the trade-off of studying one atypical participant in-depth with studying multiple participants in general, George and Bennett (2005) suggest this gives future researchers an opportunity to derive new hypotheses, as illustrated in *Figure 3.1*.

A case study researcher asks the participant:
"Were you thinking X when you did Y?", and get[s] the answer,

[↓]

"No, I was thinking Z," then if the researcher had not thought of Z as a causally relevant variable, she may have a new variable demanding to be heard (George and Bennett, 2005, p. 20).

Figure 3.1. Deriving New Hypotheses from Studying an Atypical Case
Source: Text adapted from George and Bennett, 2005, p. 20.

In this way, an advantage is gained by studying a large number of variables based on the multiple sources of data collected to capture unexpected features. Because inquiry is complex and multifaceted, the study is framed to have an absence of assumptions with what piece of evidence may offer insight to support the understanding of inquiry instruction (Kagan, 1990). As the literature review suggests, clarity on inquiry is needed; yet, problems persist with identifying the type of data that may support this knowledge. Based on information captured from this single case, the results could offer USA teachers and researchers new ideas, hypotheses, and "best-case scenarios" (Capps and Crawford, 2013, p. 522). This knowledge would be an opportunity to reflect on how to communicate inquiry, as American teachers start a dialogue to make clear the meaning of inquiry.

Furthermore, Flyvbjerg (2013) notes the common misunderstanding of attributing single case studies as useless. He cites studies throughout history noting its influence in advancing science knowledge. In particular, he demonstrates the capacity of single cases to "clarify the deeper causes behind a given problem and its consequences than to describe the symptoms of the problem and how frequently they occur" (Flyvbjerg, 2013, p. 181). In this way, the atypical secondary science teacher who is skilled in inquiry instruction in England might clarify some of the deep problems with viewing and understanding inquiry as well as factors that influence inquiry. It could also offer teachers a way to vicariously experience the participant. That is, through reading this work, other teachers may ask questions, anticipate problems, and proactively engage in discussions for coming to a shared understanding of inquiry. Teachers and researchers, for instance, may anticipate pitfalls and take an initiative to better communicate inquiry instruction.

3.3. Pilot Study

Given a plan to design a formal case study over a period of time, I also try out features of my data collection by conducting a pilot study. The key purpose of the pilot is to refine my interview queries and vignette scenarios to strengthen the internal validity of the work for the formal study (Glesne, 2011). In particular, this information is used to help clarify words and phrases for the protocol texts; this is reviewed in the section, *Data Collection*.

Along with preparation for the formal work, I use the pilot study for logistical reasons. Conducting an investigation in the real world is complex, and unforeseen events may arise. One example would be the withdrawal of the formal case participant (Knight, 2002); if this happened, then I aimed to have data available from the pilot case participant to analyse and present based on the same rigour used to select and recruit the skilled formal participant.

3.4. Sampling and Recruitment for Pilot Study and Formal Study

This section specifies the way I choose participants. With this research, I aimed to engage with an individual who is not only a secondary science teacher leader motivated to use inquiry, but who is also skilled and knowledgeable with inquiry instruction in England. For this reason, I use a purposive sampling strategy to recruit teachers. This approach gives me a way to deliberately study an atypical secondary science teacher, when compared to a typical teacher in England. Other sampling strategies, such as convenience and random sampling, could be weaker and ineffective respectively for my intention as they fail to capture the type of teacher I plan to study; accordingly, purposive sampling is valuable for my research aims.

For the purposive selection process, I reflected on research in the literature review claiming to ask exemplary teachers. With these studies—Breslyn and McGinnis (2012) and Capps *et al.* (2013)—I was critical of the way the authors defined exemplary and its relationship to inquiry understanding. Accordingly, I searched the literature on recruiting professionals with exemplary skills from other fields. In medicine, I noticed that senior members who had knowledge of physicians would be able to seek out those recognised as exemplary in their practice (Langley and Till, 1989). I also learned that asking such chiefs or directors would be fruitful as they have experience with the exemplary skilled participant as well as "their knowledge of evaluations and learner feedback" (Fromme *et al.*, 2010, p. 1906).

In order to search for [redacted] expertise not only in the field of secondary science teaching, but also inquiry instruction in England, I reached out [redacted] eligibility criteria for recruitment included exemplary inquiry instruction skills and academic knowledge of inquiry, [redacted]

- [redacted]

[redacted]

[redacted] forwarded emails to me of those who expressed interest. Three candidates conveyed interest to participate as a case. *Appendix A* presents the schedule of events following this contact. Based on email exchanges, I set up a day and time to meet face-to-face separately with each candidate across England. After these meetings, two of the candidates responded immediately to my follow-up email to schedule interviews and observations. The third candidate, however, failed to respond to my email following our initial meeting to schedule interviews and observations; in this event, I checked the status of this candidate with two subsequent emails sent over a period of two months, and there remained an absence of response. In this instance, the two candidates who replied were selected; one candidate was distant in geographic proximity whilst another candidate was close relative to my residence at Homerton College, University of Cambridge. To be resourceful with travel funds, I selected the distant candidate to be the pilot case as the purpose of this part of the study was to spend some time with one candidate to refine interview questions and vignette scenario protocols for the formal case study. With the formal case, I selected the near proximity candidate reasoning I may be able to use capital efficiently, and I would be able to use the savings to travel frequently for data gathering (Yin, 2014).

Prior to starting the study, I obtained consent from the institutional review board at the University of Cambridge Faculty of Education. I also received written informed consent from the teacher. A Disclosure and Barring Service check was also obtained. I was invited to the school once the teacher gained permission from their heads of department for me to observe inquiry classrooms. Since I intended to focus on the teacher, rather than students, there was an absence of requirement of individual student consent. When I visited schools, I was under the supervision of the teacher; during this time, I signed in at the main desk and I was given a visitor necklace, which I wore for the duration of the visit; then, I signed-out of the school once I had finished my observations.

Finally, for internal validity, an audit trail was used to document the attrition status of the third teacher (B. Rodgers, 2007). This teacher had initially responded [redacted] yet lacked responding to emails after an initial face-to-face meeting. Information from the audit trail was useful to review that the absence of correspondence was due to a compromised email. *Figure 3.2* illustrates this.

Email Response from Teacher

Third teacher responded [redacted] email to express interest in participating as a case study.

↓

Meeting with Teacher

By email, I set up a time to meet face-to-face with the teacher who expressed interest.

↓

Post-meeting email sent

Follow-up email sent after face-to-face meeting; there is an absence of response.

↓

Two subsequent emails sent

Two follow-up emails sent; there is absence of response from the teacher over a period of two months.

↓

Audit trail used

To document attrition for credibility purposes, contact information was reviewed from a chain of email logging records. Along with email address, text number was found to send a message respectfully to minimise intrusiveness (Anfara *et al*., 2002). I used both communication tools and, by text number, the teacher responded. This teacher wrote that the inaccessibility and absence of correspondence was due to a compromised email account. I thanked the teacher for the response. I also reflected on whether I should correspond with this individual during the final stage of my investigation of mid-May 2015; [redacted] I considered the original aim of the research, which was to capture in-depth information. Since this work was already in-progress, and because the investigation focused on engaging with the participant over a period of three months for the purposes of deep understanding, I reasoned that adding another case would be out of scope at this stage of the Masters Program from an ethical[xiii], objective, and logistical perspective. Time and funds would not only be needed for travel but also for data collection, analysis, and member checking to maintain standards of credibility and reliability.

Figure 3.2. Using an Audit Trail to Document Attrition Status of Third Teacher
Source: Author's Logging Records from email.

[xiii] From the teacher's perspective, I considered the ethical aspect of beneficence. I asked myself if the teacher would benefit with my short-amount of work. Given a limited time to interact with this third teacher, when compared to the two participants already involved, I anticipated that the data collection might get rushed and move away from the purpose of in-depth understanding of inquiry instruction. In this way, hasty data collection and analysis may be considered unfair for the teacher. Broadly, this could also compromise the overall findings from a societal perspective.

4. METHODS

I now turn to the methods used to conduct the investigation. This chapter starts with the sources of data collected. It then illustrates the analysis procedures used to interpret the data. Following this account, I show the steps taken to maintain reliability and validity for this work.

4.1. Data Collection

Several data sources were used. In this research, the key data source was interviews. Observations, vignettes, and artefacts supplemented this work. This section reviews the contribution from each source.

Interviews were at the heart of this research. I planned to conduct two interviews. In particular, the first interview was designed to capture holistic views and understandings on inquiry, as well as views on factors that promote and constrain inquiry instruction. Then, after observing lessons, I aimed for a final interview in order to gather participant reflections on those lessons; I would also ask about vignettes I would present that day for the purposes of triangulating the findings and seeking synergies. To do this, I audio-recorded and transcribed verbatim the interviews. In the pilot study, I conducted the interviews at a coffee shop, as this was suitable for the participant. For the formal study, I conducted the interviews at a quiet room in the participant's home, again, to respect their preference.

At the start of the interview, I offered the participant a hardcopy of the interview questions to make them comfortable (Seidman, 2013). For instance, if the participant misheard a question, they could take time to review the hardcopy questions to reflect and respond. Interviews were shaped using a semi-standardised technique, which involves pre-designed queries focusing on my two study research questions (Berg and Lune, 2013). Semi-standardised also gave me a chance to probe beyond the queries to clarify understanding. This would happen, for instance, when I ask: What would happen in that case? What are some specific examples?

I piloted the interview text and questions. This pilot feedback was useful to enhance the flow and questioning for the purposes of clarifying linguistic differences and gaining depth in responses (Seidman, 2013). The changes were made to several queries to improve the clarity of protocol. In particular, with one query, 'what is the way you define inquiry instruction', the pilot participant appeared to be struggling so I removed this, as it was repetitive to the query of 'how do you define inquiry instruction'; the latter query was simpler. Along with that, I removed a sub-query, 'what factors need to be present for you to use inquiry instruction', to add focus since this item was asked later in the interview. I also edited another sub-query to ask 'at which times' rather than 'are there specific times' the teacher used inquiry since the pilot participant had trouble understanding the latter version.

In this pilot work, I also received feedback on queries focused on factors influencing inquiry. Based on this, I changed the terminology from 'what factors support' to 'what factors promote' in order to standardise the language used with my research question. I also removed two sub-queries, which asked how the participant felt about 'the number of students as a factor influencing inquiry' and 'what policies support the use of inquiry'. I justified both of these removals since it could improve the flow of the questions for the participant; also, it was out of scope and repetitive with the rest of the queries. After this interview, a protocol (*Appendix B*) for the formal case study was designed with seven queries. On the next page, *Table 4.1* portrays the interview protocol for the formal study and highlights the changes made.

Table 4.1. Queries in the First Interview for the Formal Study

Research Question	Queries for the First Interview in the Formal Study*
What are the views and understandings of an exemplary secondary science teacher on inquiry instruction in England?	1. How do you define inquiry instruction? i. How do you feel about inquiry instruction as a pedagogical practice? ii. At which times would you use inquiry instruction? 2. What is your goal for inquiry instruction? a. "What do you want students to learn?" b. "How will you know what students are learning?" c. "How will you respond when they do not learn?" (National Research Council, 2013, p. 135). 3. What are your views and understandings on inquiry instruction?
How does an exemplary secondary science teacher reflect on factors that promote and constrain the use of inquiry in England?	4. What factors promote your use of inquiry instruction? a. What factors need to be present for you to use inquiry instruction? b. What types of curriculum materials are used for inquiry? c. How are time and resources allocated for inquiry? d. How do you feel about policies around inquiry instruction? 5. What factors constrain your use of inquiry instruction? a. What policies constrain your use of inquiry? 6. Do you think the National Curriculum has an influence on the way you use inquiry instruction? 7. If you were the researcher, what question would you ask to secondary science teachers about inquiry instruction? a. How would you improve the use of inquiry instruction?

Source: The author wrote queries 1, 2 main, and 3-7. Of note, sub-queries 2a, 2b, and 3c were referenced in Appendix K from the National Research Council (2013). In this work, the queries asked USA secondary science teachers to articulate learning as new science standards, the Next Generation Science Standards, were added to states, with expectations of full implementation by 2025. The National Research Council wrote these queries as "we" to probe teachers in the USA; for my project, I changed this to "you" to ask for the pilot and formal study in England.
*In this table, the shaded text notes sentences added to the formal study based on pilot study feedback; non-shaded cells note queries that remained the same. Finally, as explained in the previous paragraph, feedback from the pilot study was also used to remove several queries to tighten the formal study interview.

Whilst interviews offer insight to participant views, there are also drawbacks. In particular, interviews are based on "what the informant said, [and is] not a direct understanding of his or her perspective" (Maxwell, 2005, p. 94). Accordingly, I wanted to capture evidence by observing how teachers practice inquiry and ask teachers questions about this. In this way, I use unstructured observations. With this, a key strength is to challenge or support information from the interviews; it would also offer a contextual layer to ask about in the final interview (Bogdan and Biklen, 2006; Glesne, 2011). In this way, I avoid the limitation of relying on perceptions and self-reporting from interviews, which, if relied on solely, could introduce bias

(Goodman, Kuniavsky, and Moed, 2012). I had thought of piloting the unstructured observation document; but, due to scheduling conflicts with the pilot participant, this was inevitably not possible in time prior to conducting the formal study.

To conduct observations, I asked the participant to show me lessons that demonstrate inquiry instruction in England. The participant was free to select the lessons; as done in past work, this choice may offer the participant a chance to show their top lessons and to act as best-practice scenarios for me to observe inquiry (Capps and Crawford, 2013). Prior to starting the observation, I asked the participant where to sit in order to respect the class and minimise interference with the day-to-day lesson. I sat in the back for all lessons. I used my password-protected laptop and, with a text document (*Appendix C*), I captured background information, context, and set up of the classroom at the start of the lesson; this included materials placed around the classroom, if applicable, as well as writing on the board or projector. In this document, I also noted the dialogue. I time-stamped this information every 5-20 minutes.

As mentioned earlier, once conducting observations I planned to carry out a final interview not only to ask about the lessons but also to capture feedback from vignette scenarios on inquiry. Unlike observations, the purpose of vignettes are to gain a clear view of the participant's understanding of inquiry by asking them questions about lessons from the USA; a key strength of using American vignettes is to gain 'outsider' feedback on lessons that American teachers and researchers would be familiar with (Loughran, 2014). Importantly, vignettes capture fresh perspectives on inquiry lessons for American researchers as they begin to transform their science education framework akin to that established in England. Based on established inquiry lessons in the USA, I wrote the first vignette to give the participant a chance to reflect on a short biology lesson on the influence of genes and the environment on behaviour (Weigel *et al.*, 2014). Then, I wrote the second vignette to ask the participant about engaging students with 'messy data' over several physics lessons (Gould *et al.*, 2014). Before introducing these vignettes in the interview, I piloted the text and questions.

With vignettes, I gained feedback from the pilot study participant. To do this, I visited the participant in her school whilst she was on lesson break to respect her convenience. The comments were helpful to shape several areas of the final text. First, I clarified the phrases at the beginning for both vignettes. In particular, I shortened the first sentence. I also made explicit connections to the content in the National Curriculum so that the participant in the formal study may grasp how this vignette might fit into the science content in England. I also added a sentence at the end to specify the goal of the lesson. Then, with the vignette questions, I added two parts: what are the views and understandings as well as thoughts on how this may influence student learning; this edit was used to better structure the questions since the pilot vignette questions only asked about factors. Finally, for one vignette, I marked a personal note. The pilot participant seemed to take time to visualise the physics inquiry vignette; accordingly, I anticipated this for the formal study participant. Based on this feedback changes were made. On the next page, *Table 4.2* illustrates these changes, which are highlighted to design the final vignettes.

Table 4.2. Vignettes and Questions for the Formal Study by Discipline

Discipline	Text*
Biology Vignette	Mr Sand is doing a biology lesson for 9th grade students to help them learn that behaviour is a trait that is shaped by both genes and the environment. In England, this would relate to Key Stage 4 students engaging with the biology content of "how the genome, and its interaction with the environment, influence[s] the development of the phenotype of an organism" (Department for Education, 2014c, p. 9). This lesson would take about 1 to 2 classroom sessions that are 50 minutes each. With this work, students would confront their prior knowledge of behaviour and its relationship to genetics and the environment based on scientific papers; these students would construct models demonstrating behaviour is controlled by genes and the environment. Students would then collect biology data to make hypotheses and predictions to link concepts of genes and environment of behaviour functions and evolution.
Physics Vignette	Ms Williams is preparing a physics lesson for 9th grade students to detect extrasolar planets or "planets that orbit stars similar to our own Sun" (Harvard-Smithsonian Center for Astrophysics, 2015, p. 4). In England, this would relate to Key Stage 4 students engaging with the content of "space physics" (Department for Education, 2014c, pgs. 16-17). This lesson would take about 5 to 10 classroom sessions that are 45 minutes each. Since current telescopes can rarely see extrasolar planets directly, an indirect method would be used called "planetary transit". With this work, students would use a web-based telescope [*personal note: show the lesson plan which describes this*] to collect data by taking images of a target star to look for a dimming of starlight. Students see the dim when an exoplanet passes in front of a star and eclipses the light for a short time. During this time, students would measure the brightness of a star and graph it over time to see the dip. Like scientists, students engage with the "messiness of real data" and analytical work "to separate the signal from the noise in their investigations" (Harvard-Smithsonian Center for Astrophysics, 2015, p. 3).
Questions	-Thinking about how you would teach this lesson in England, what are your views and understandings about it and its relationship to inquiry? -How do you think this may influence student learning? -What factors may promote the use of inquiry? -What factors may constrain the use of inquiry?

Source: The author wrote the vignettes and questions. The biology lesson is based on Weigel *et al.* (2014); the physics lesson is based on Harvard-Smithsonian Center for Astrophysics (2015).
*This table presents the vignettes and questions presented to the formal study participant; the shaded text marks new sentences added to the formal study based on feedback from the pilot study.

Importantly, I presented both vignettes to the formal case participant in the final interview. In this session, I first asked about the lessons I had observed. Then I asked about both vignettes. And then I asked two demographic questions, which included how the participants learned about inquiry as well as qualification of being skilled and knowledgeable with inquiry. *Appendix D* presents the vignettes and questions presented in the final interview.

Finally, artefacts were collected to offer context to the interviews and observations. This included internal artefacts, made by the teacher, and external artefacts, which were designed by exam boards. I actively asked for artefacts during the study. And the participants emailed me artefacts during this period. Specifically, the pilot case participant sent two external artefact examination board[xiv] schemes of works; this teacher noted that one was provided to the school, and the other was a version edited and modified by the school. The pilot participant sent me one internal artefact, which was text of a lesson plan written by the teacher. Then, the formal case participant provided two external artefacts, which were National Curriculum specifications written by two other examination boards[xv,xvi] that the school used as schemes of work. The internal artefacts included two PowerPoint lesson plans made by the teacher. To control for the number of artefacts, during the final interview I made a verbal request for artefacts, including student-based work; I also wrote an email message after my final interview to formally ask a final time for artefacts[xvii].

This part summarised the strategy for data collection. By piloting the interview and vignettes, I was also able to edit texts for the formal study; to respect space limitations, pilot descriptive findings from the unrefined text are placed in *Appendix E*. With refined tools, I gathered data for the formal study. The next part turns to the steps taken to analyse this information.

4.2. Data Analysis

I now turn to the steps taken to examine information from data sources in the formal study. Since this is interpretative work, I pay attention to actively challenging claims and patterns discovered whilst conducting the analysis. A systematic approach is used. I follow a sequence of steps, and I write memos to be reflexive throughout the analysis.

In the first step, I read the transcript interviews at least three times. The first and final interviews lasted 45 minutes and 60 minutes, respectively. This yielded 53 pages of verbatim transcript. With each interview, I intently read the text and asked myself if

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[xiv] Edexcel is "the brand name for academic and general qualifications from Pearson" (Pearson, 2015).
[xv] The AQA "are an independent education charity and the largest provider of academic qualifications taught in schools and colleges" (Assessment and Qualifications Alliance, 2015).
[xvi] The OCR aims to "provide qualifications which engage people of all ages and abilities at school, college, in work or through part-time learning programmes" (Oxford Cambridge and RSA, 2015).
[xvii] Student work was unavailable (Formal case participant, personal communication, May 5, 2015).

there was terminology that I was unfamiliar with and, in this instance, I would aim to learn the new terminology by reviewing the definition or explanation offered in the text. As I read the text, topics focusing on the two research questions were conspicuous given questions explicitly asked about this. These responses ranged from one sentence to several paragraphs. I then actively searched to discover new topics articulated by the participant (Kuckartz, 2014). During this process, I wrote notes next to the transcript to summarise sentences and paragraphs to aid interpretation. I also made memos on index cards. In particular, I wrote memos to record "any thoughts, ideas, assumptions, or hypotheses that occur…during the analysis process" (Kuckartz, 2014, p. 52). This helped mark peculiarities, such as information that was surprising and intriguing to track my assumptions (Sustein and Chiseri-Strater, 2007); for example, based on the final interview in the formal study, *Figure 4.1* illustrates a memo raising a discrepancy between the way this participant classifies an inquiry lesson with the way classified in literature.

MEMO June 10, 2015

I also notice this teacher uses the word[s,] "was the most open" to [classify] a lesson [of inquiry.] […However] in the older literature by Schwab (1962), [the teacher's lesson] would be classified as guided inquiry since the [literature defines guided inquiry to be: the] teacher is responsible for [posing] the question whilst the student comes up with the activities.

Figure 4.1. A Memo Note that Marks Peculiarity
Source: Author's Memo. Of note, brackets are added to support reading of verbatim text in the memo.

After reading transcripts multiple times and writing memos, I started to categorise the responses. I use the terminology 'categorise' to start analysis by labelling text; the end product is a construction of 'themes' (Kuckartz, 2014)[xviii]. This drew on the research questions to focus on three objectives—the views and understandings on inquiry, reflections on factors promoting inquiry, and reflections on factors constraining inquiry—using a general inductive approach (Thomas, 2006). The goal for creating the categories was to label the participant's response using their words verbatim rather than designing abstract categories. To facilitate this categorisation, I built a database in Microsoft Excel to organise and analyse in-depth information (Meyer and Avery, 2009). I read the transcript sequentially line-by-line and

[xviii] Other researchers, such as grounded theory analysts, may use the term 'code' to start analysis by labelling text. Their end product is a construction of 'categories' or 'themes'; they define 'categories' to mean the same thing as 'themes' (Merriam, 2009).

constructed a category made of several words stated by the participant to reduce complexity, whilst retaining the rigour of the content (Knight, 2002). Then, if subsequent paragraphs in the transcript matched with a constructed category, I linked it with that category; if it was different, I made a new category. Over time, as this system progressed and categories developed, I sought to use prudence in grouping categories to form grouped categories; or, if grouped categories were reasoned to be broad, they were split in order to reduce overlap and comprise an appropriate number of categories (Kuckartz, 2014). I also looked to develop a category for discordant information from those categories designed. This 'bag' would contain counter-examples for reflection as more information was collected from observations, vignettes, and artefacts (Mason, 2002); in particular, I aimed to lessen the chance of clutching to provocative text so that I may gain a holistic sense of data.

In the second stage, I compared and contrasted the categories from first and second interviews. Then, for the three main objectives, I asked myself: "What do respondents have to say about this topic? What do they leave out or only mention briefly?" (Kuckartz, 2014, p. 84). I wrote and reviewed memos to capture thoughts and counter-examples from the 'bag' in step one to be reflective, and to bracket potential biases (Peshkin, 1988).

Based on these two steps I began to develop themes by searching for repetitions, and by looking at keywords in context, for finding dissonance, across the interviews (Ryan and Bernard, 2003). *Appendix F* shows an example of repetition analysis to find a theme for the first objective: views and understandings on inquiry. *Appendix G* presents the final scheme with five themes. On the next page, *Figure 4.2* illustrates the process from constructing categories to creating themes.

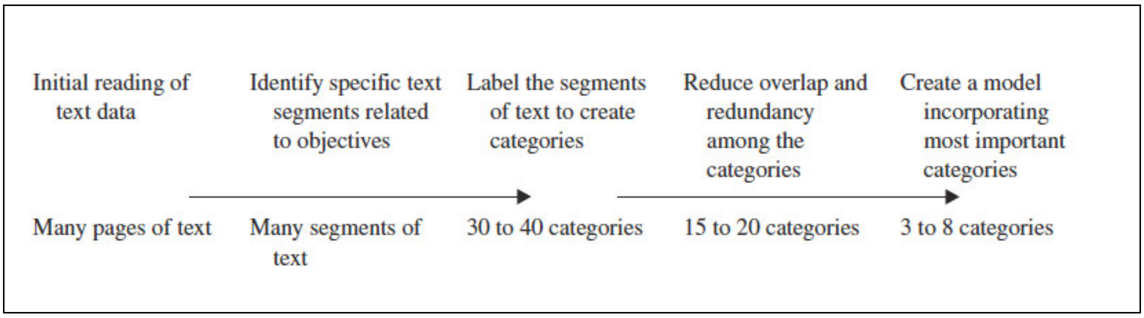

Figure 4.2. Inductive Analysis of Interview Text to Create Themes (i.e. a model)
Source: Creswell, 2002, p. 266, Figure 9.4. Of note, in this figure, Creswell (2002) uses the word 'model' as a way to present the 3 to 8 themes—that is, the final '3 to 8 categories'.

In the third stage, I aimed to search for discrepant and concordant data from observations and artefacts. This third stage was used to offer balance and alternate explanations to the analysis conducted from the prior two stages of interview analysis. For observations, I witnessed three lessons with the formal participant each with different students; lessons lasted from 60 to 100 minutes, and this yielded 12 pages of observation notes. For each observation, I read the completed time-stamped dialogue line-by-line to look for patterns of participant words and participant interaction with students; based on this evidence, I asked how the participant engaged whilst using inquiry. What were common patterns? What were different patterns? These exploratory questions were useful to capture routine and unexpected features of inquiry lessons by comparing them with interview findings (Clark and Leat, 1998; Mehan, 1979). For instance, features included phrases a participant frequently used at the beginning, middle, and end of the lesson. *Appendix H* presents an example of the observation analysis. Alongside this, I examined artefacts; I asked key questions, including: "Who writes them? For what purposes? How are documents [i.e. artefacts] written?" (Hammersley and Atkinson, 1995, pp. 142-143). These questions offered contextual depth to interviews (Silverman, 2014). As an example, *Appendix I* presents the artefact analysis. Overall, in these steps, I maintained an attitude of scepticism to avoid early conclusions and to take time in analysing all information (Kemp *et al.*, 2014; Strauss and Corbin, 1990). Now, I turn to my role in the analysis.

4.3. Reflexivity

This section extends the discussion on analysis. Since this work is interpretive in nature, I reflect on my perspective and experience for transparency. This is to respect the view that "if you don't declare it, you will take in, surreptitiously, assumptions or expectations that will colour what you see and how you see it" (Richards, 2015, p. 29). Previously, I was a science teacher. Now, I am a researcher; I disclosed this to participants to note that I had interests to make clear inquiry instruction and participants could have, inadvertently, tended to suggest a more positive outlook on inquiry.

In the USA, I have also carried out classroom observations to observe inquiry instruction in secondary schools using an instrument approved by the National Science Foundation. This instrument is called the Reformed Teaching Observation Protocol and it is used to capture teacher and student dialogues, activities, and interactions (Sawada *et al*., 2010). I was trained to score participants based on questions focusing on lesson design and implementation, content, and classroom culture. I acknowledge this protocol was built on the theory of constructivism.

In contrast, with this study in England, I sought an exploratory goal. I am genuinely interested in gaining deep understanding of inquiry instruction in England from the skilled teacher since there is confusion amongst teachers in the USA. To support this purpose, I analysed the text for inductive purposes rather than rely on structured protocols using a deductive framework. I also used language the participant voiced to explain and interpret the work (Kuckartz, 2014). Also, wary of my background with observations in the USA, I became concerned of interpreting data based on what I was familiar with. Accordingly, I wrote memos to critically engage with the words the participant spoke to justify the analysis and to reduce the threat of bias from categorising based on theory or personal experience (Taber, 2012). To this end, I aimed to stay true to the participant's responses. I also engaged in more formal validation techniques explained below.

4.4. Validity

Whilst the previous section explained my personal stance, this section turns to the validity of the work. Since this is qualitative research, the focus is on credibility or internal validity; and transferability or external validity (Lincoln and Guba, 1985). First, I sought credibility, that is, with my steps in collecting and analysing the data.

In particular, I triangulated the data, compiled an audit trail, employed reliability checking, and applied response validation. With triangulation, I aimed to collect multiple sources of data to systematically search for evidence that would challenge and corroborate information as well as seek alternative explanations.

In addition, I sought to use an audit trail to be prudent in documenting my steps using a secure notebook. This was useful for detailing correspondence with the participants, collecting artefacts, and developing categories in the stages of data analysis. Further, reliability checking was conducted. At the Cambridge Faculty of Education a final year doctoral student, experienced in conducting qualitative research and leading a writing and analysis group for graduate students, checked 20 per cent of all interview-and-vignette text to ensure clarity of categories and appropriate content analysis (Thomas, 2006); the literature suggests to conduct at least 10 per cent checking (Lombard, Snyder-Duch, and Bracken, 2002). Along with that, I engaged in response validation to gain feedback on the findings. This was useful to avoid misinterpretation of participant views (Maxwell, 2005). To do this, I corresponded by emailing. For example, *Figure 4.3* shows a response of checking the final themes and their organisation to the research objectives. This feedback was useful to review the empirical analysis, and show nuance to the theme of 'School Resources' as a constraint to inquiry.

<u>Email of Original Themes and Organisation</u>:

"Views and Understandings on Inquiry
-Independent Activity
-Explore Topic and Reveal Misconceptions

Factors Promoting Inquiry
-Student Knowledge and Behaviour
-School Resources

Factors Constraining Inquiry
-Drive to Show Measurable Attainment"

→

<u>Email Response of Formal Case Participant</u>:

"All looks great ! My only correction would be that 'school resources' might be more appropriate in 'Factors Constraining Inquiry' as the lack of resources can be a real restriction. Of course it is also appropriate in 'Factors Promoting Inquiry' as having good quality and abundant resources can really make Inquiry lessons work!"

Figure 4.3. Response Validations on Themes Developed and their Organisation
Source: Author's Email (Formal Study Participant, personal communication, June 22, 2015). Based on this, I reviewed the empirical data to justify the change (Merriam, 2009). In the final analysis, I placed the theme of 'School Resources' in the research objective of 'Factors Constraining Inquiry' with the comment: this could be a factor promoting inquiry if there are good quality and abundant resources.

Based on this response validation feedback, I re-analysed the theme of school resources and its category-based evidence. As an example, in the first interview the participant offered a rich scenario of his reflection on factors promoting and constraining inquiry. At the beginning, the participant notes resources to promote inquiry; at the end, the participant adds a hypothetical situation noting that in the absence of resources inquiry would have been difficult. The participant explained:

- "[Students had] laptops and leaflets, posters and textbooks from different periods of time and textbooks from different areas in different countries and all that kind of thing. They could really explore their own work. So one student was comparing drug use in different countries, one student was comparing drug use across time. So kind of how people's views to drugs have changed. Others went down the more obvious biological-chemical route. But without those resources, they couldn't have done that. They would have all done: 'How does cannabis compare to heroin compare to ecstasy?' Because they're the three drugs in the textbook. So that would have been their only option" Transcript (First Interview, 13 March 2015, pp. 8-9).

Here, the participant described having the resources yet notes that an absence of resources could make this difficult. At the end of this interview, when asked a question explicitly on factors that constraints the use of inquiry, the participant mentioned, "it's very difficult to convince your department that you want to use all of the practical equipment [for] one day because other people need it and things as petty and silly as that" Transcript (First Interview, 13 March 2015, p. 14). Indeed, this evidence along with data from an observation in which students extract DNA from kiwi cells, the participant cautions students about resource limitations; this is explained in the Findings chapter.

Along with response validation, an important part of this research is the selection of a secondary science teacher who is knowledgeable and skilled in using inquiry instruction. Given my critique of past work[xix] classifying teachers as exemplary in the literature review, I sought to be careful in this study in England. Accordingly, I studied academic research in different fields. [redacted] In one robust study, I also learned recruitment of exemplary physicians involved the selection criterion of consensus amongst multiple chief members (Fromme *et al.*, 2010). [redacted] In England, I asked multiple senior members[xx] and they kindly reached out to assist; [redacted]

From an external validity perspective, this research was not intended for generalisability purposes. However, I planned to offer in-depth results for the teacher audience in the USA. Given a sample size of one participant, rather than engage in transferability, I sought for USA teachers to consider ideas from the atypical participant in England. To do this, I aimed to present the constructed meaning of inquiry from the viewpoint of the participant for rich interpretation (Cho and Trent, 2006). Unlike writing a superficial account of a case study, through thin description, I describe specific aspects of the participant to provide thick description (Geertz, 1973; Holloway, 1997), whilst balancing anonymity and confidentiality.

In this chapter, I presented the methods of the study. I focused on data gathering and analysis. I also took steps to reflect on my stance in this research, and to preserve

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[xix] In particular, I critically analysed two studies investigating exemplary teachers in the USA (Breslyn and McGinnis, 2012; Capps and Crawford, 2013).
[xx] [redacted]

validity. The next chapter extends this by considering ethics whilst conducting data collection.

5. ETHICAL CONSIDERATIONS

Along with validity, I also reflected on two sides of ethics: first, respecting and protecting the participants; and second, responsibly conducting a professional investigation to contribute new knowledge to the public. To achieve these goals, I abided by a set of ethical guidelines and used informed consent. I also consulted a framework to achieve ethical research. I report these pieces below.

Since this study was set in England, I adhered to the ethical guidelines set up by the British Educational Research Association (2011). I paid attention to ensure trust (Tschannen-Moran and Hoy, 2000). In addition, as described in the data collection section, prior to starting the study I used typewritten informed consent (*Appendix J*) to communicate the research and indicate the voluntary aspect of participation. In this piece, I delineated the features of the study, including the password-protected way of storing data, achieving confidentiality as well as anonymity, and respecting the right to opt out. Also, I explained the absence of compensation, the potential risks and benefits, and the steps to check the work with the participant.

I also reflected on ethical principles to justify my actions. In particular, I used an ethical framework for educational research (Stutchbury and Fox, 2009). *Table 5.1* below explains the framework in the layers of relational, deontological, utilitarian, and ecological; this was useful to systematically reflect on as I carried out my investigation. In this way, I critically engaged with the relational aspects of trust, the deontological openness, the utility for participants, and the respect for ecological environments.

Table 5.1. Ethical Framework for Educational Researchers by Layer

Ethical Layer	Explanation
Relational	Establish trust and build a genuine and constructive relationship with the participant.
Deontological	Be open and honest with the participant in this investigation to avoid wrong.
Utilitarian	Consider the benefits of this research for the participant.
Ecological	Respect the norms and values of the participant environment to be culturally sensitive.

Source: Adapted from Stutchbury and Fox, 2009, pp. 495-496, Table 2.

Based on the table from the previous page, I reflected on my ethical role of professionalism when one participant in the study had an occasion[xxi] unrelated to the study. In the USA, this occasion would be given professional attention. But since I was in England conducting research, I wanted to abide by local norms and customs. To do this, I consulted with my supervisors on the manner to act. This preparation allowed me to acknowledge the occasion whilst maintaining professionalism with the participant. Importantly, the ethical framework helped me build a genuine relationship in a culturally sensitive way.

Along with building a genuine relationship, as briefed in the section of Sampling and Recruitment, whilst conducting the audit trail I also reflected on the ethics of utility for the third teacher who had lost contact by email. In particular, reflecting on the issue of beneficence and respecting teacher time allowed me to engage in a principled manner. Given these considerations, in the next section I present the findings.

[xxi] Of note, I phrase it this way to preserve anonymity and confidentiality for the participant, and to respect the demands on researchers in the twenty-first century (Tilley and Woodthorpe, 2011).

6. FINDINGS

Whilst the prior chapter traced ethics, I now present the findings. I begin by describing the context in England. Then, the sections detail the themes that emerged from the data analysis. Five themes were constructed to answer the research questions. To preserve confidentiality and anonymity, pseudonyms are used for the participant and context.

6.1. Participant Context

In this research, the participant was well qualified and taught all science subjects. The participant instructed in a school with some diversity [redacted] Inquiry instruction was practiced in a typical science classroom with a 'U-shaped' seating arrangement. Three inquiry lessons were observed. A profile of the participant and the inquiry lessons observed are presented in *Tables 6.1* and *6.2*, respectively. To ease citation, from here I name Jack as the participant. The next section notes the themes of views and understandings on inquiry.

Table 6.1. Profile of Participant

Participant Name	Gender	Professional Background	Qualification	Subjects Taught	Years of Teaching Experience	School Teaching
Jack	Male	[redacted] Secondary Science Teacher	PGCE; [redacted]	Biology, Chemistry, Physics	6	State

Source: Transcript (Final Interview, 2 May 2015, pp. 31-33). Of note, teacher name is a pseudonym. In England, PGCE is Postgraduate Certification in Education.

Table 6.2. Profile of Three Science Inquiry Lessons Observed

	Extracting DNA from Kiwi Cells	Effect of Temperature on Cell Membrane	Impact of Human Extinction on Earth
Inquiry Type*	Much More Structured	Partially Structured	Most Open
Aim of Inquiry Activity	Investigate the effect of temperature on cell membrane by engaging in practical skills	Write a method for extracting the DNA from Kiwi Cells; use the equipment provided to extract the DNA	Investigate a question: "What would happen to the Earth if Humans were wiped out overnight?"
Equipment Used	Laboratory materials	Laboratory materials	Mini-laptops
Independent Style	Individual	Small group; pair; individual	Small group; pair; individual
Grade Level	Year 12 Key Stage 5 Biology	Year 10 Key Stage 4 Biology	Year 11 Key Stage 4 Biology
Number of Male Students	4	26	9
Number of Female Students	5	0	17
Total Number of Students	9	26	26
Duration	100 minutes	60 minutes	60 minutes

Source: Unstructured Observation Documents; Artefacts; and Transcript (Final Interview, 2 May 2015). Of note, the lesson of Effect of Temperature on Cell Membrane lasted for one class. The lesson of Extracting DNA from Kiwi Cells also lasted for one class. On the other hand, the lesson called Impact of Human Extinction on Earth continued for two more class sessions over the weeks; I observed the first class, and the participant offered feedback in the final interview for the following two classes. *According to the participant description, Much More Structured inquiry is teacher giving students a method to follow. Partially Structured inquiry is teacher giving students information and students using this to build a method. Most Open inquiry is teacher giving students a question to answer in any way.

6.2. Views and Understandings on Inquiry

This section turns to the first research question. To begin, I describe Jack's views and understandings on inquiry by laying out two themes emerging from my analysis. This includes independent activity and explore topic and reveal misconceptions.

6.2.1. Independent Activity

Jack suggests inquiry instruction is any task or activity where students pursue something independently. During interviews, he contrasts inquiry with traditional teaching: "[it's] not just being spoon-fed, if you like, information from the teacher, it's more a kind of process where [students] investigate and they work things out". To illustrate this, he begins a lesson with an announcement: "We're going to do things slightly different today… Instead of just telling you facts… because we have a curriculum… you should be… as independent as possible”.

In both interviews, Jack gives several reasons for engaging students in independent activities. Broadly, “they’re more likely to retain the information and they’re more likely to go beyond the expectations of the lesson”. In particular, he seems to find these tasks building student skills and confidence. For him, “the priority is the scientific skills like experimenting and investigating and trial and error” whilst “the content is secondary”. But he also explains a tension: “You can feel the atmosphere of learning but… I find it very difficult to evidence”, later adding, “I don’t think inquiry lends itself to assessments particularly well”. Still, he notices skills development by observing and getting involved. He explains, “You can walk around… and get them to use the right words… you hear the language improve and become more scientific”.

To foster student skills, Jacks suggests using the National Curriculum. He points to one strand: “How Science Works is quite an interesting thing… it is just about [students] doing an experiment… the learning that’s taking place is how you would plan an experiment, how you would record data, how you would evaluate the data, so, because it’s just about the skills”. He notes whilst the curriculum omits to define inquiry, it does support inquiry activities.

Adding context to the curriculum, Jack shares two booklets explaining How Science Works. A close review of these pieces, though, suggests differences in the way he explains building student skills and the description of student skills in the curriculum. For example, in the interviews, he seems to skip explaining skills of recognising limits of science and making judgments about societal factors influencing science. Yet, one reason for this may be inadvertently forgetting to cite these skills. As a counter argument, he could be focusing on a few skills for inquiry activities. On the next page, *Table 6.3* syntheses these aspects and its relationship to the views of Jack.

Table 6.3. Artefact Findings on How Science Works of the National Curriculum

Artefact Booklets	Analysis and Findings
General Certificate of Secondary Education (GCSE) Specification Biology by The Assessment and Qualifications Alliance (AQA)	Jack suggests employing the AQA booklet for inquiry instruction as a way for students to engage in independent activities and build skills and confidence. In this booklet, students would be expected to plan an experiment and have repeatability, reproducibility and validity (AQA, 2011). Indeed, in the first interview, Jack suggests this: "so you plan to have repeats in your experiment. You plan to use the repeats to calculate a mean within you experiment. You'd have a risk assessment, which has a specific structure". In the final interview, whilst discussing the three lessons and two vignettes, Jack also suggests giving students a chance to think, observe, investigate, present, and draw conclusions, comparable to the How Science Works. However, absent in Jack's discussion for building skills are two parts stated in How Science Works. The first is societal aspects of scientific evidence – "a judgment or decision relating to social-scientific issues may not be based on evidence alone, as other societal factors may be relevant" (AQA, 2011, p. 9). As an example, AQA cites evidence should be checked for bias coming from funding or affiliations. The second is the limits of science – "science can help us in many ways but it cannot supply all the answers" (AQA, 2011, p. 9). In this way, AQA notes science fails to answer questions about ethics and opinions.
General Certificate of Education (GCE) Biology version 4 by The Oxford Cambridge and RSA (OCR)	Jack claims to use the OCR booklet for inquiry as independent work and, indeed, his discussions appear to conform to features of fostering skills. In particular, the appendix notes, How Science Works includes students "obtaining, analysing and evaluating data" (OCR, 2013, p. 67).

Source: Assessment and Qualifications Alliance, 2011; Oxford Cambridge and RSA, 2013.

For building skills, Jack suggests three types of activities. First, he uses the phrase 'much more structured inquiry'. He seems to see this as instruction in which teachers give students a method to follow. Second, he uses 'partially structured inquiry' as activities in which teachers give students information and students would put this together, "almost like a jigsaw", to build a method. And third, with the 'most open inquiry', Jack suggests this as a way for teachers to give students a question so students "can go in any direction" to answer it. To illustrate these inquiry types, *Figure 6.1* describes the activities as lessons progress; this is on the next page.

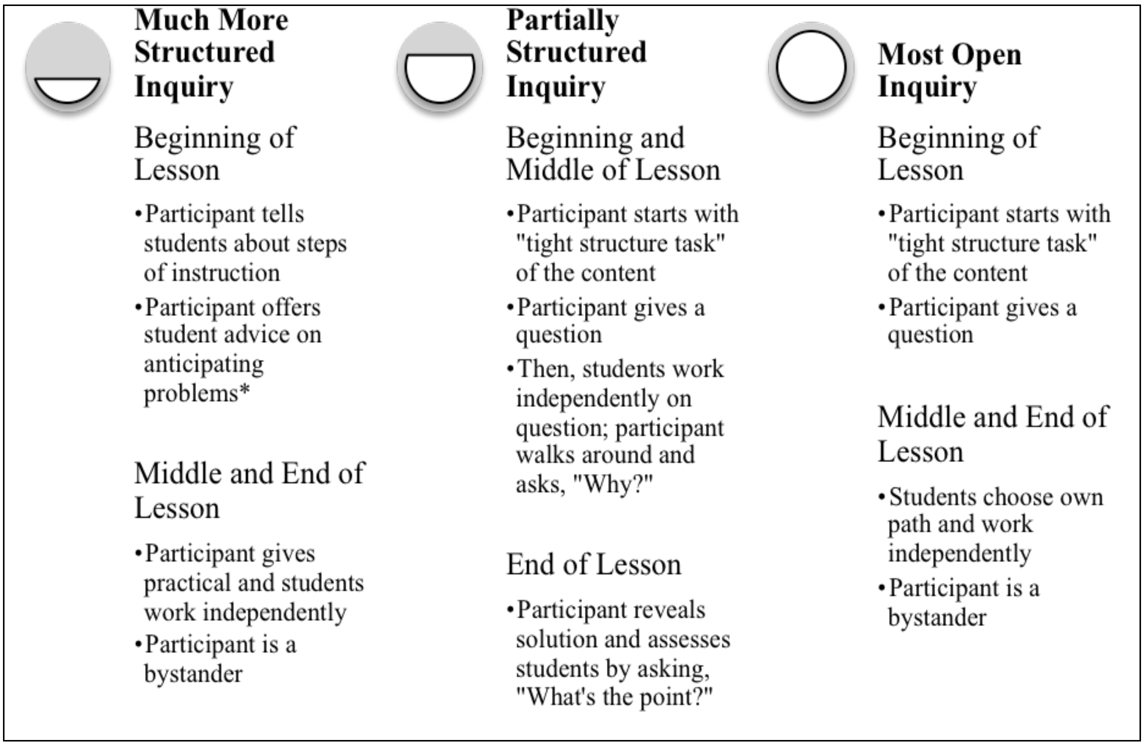

Figure 6.1. Three Types of Inquiry Lessons: From Structured to Open
Source: Author's Interpretation based on triangulating data from interviews and observations. The Much More Structured Inquiry is the lesson on the Effect of Temperature on Cell Membrane; the Partially Structured Inquiry is the lesson on Extracting DNA from Kiwi Cells; the Most Open Inquiry is the lesson on the Impact of Human Extinction on Earth. Participant suggests "tight structure task" to introduce the topic to students; for example, with the Human Extinction lesson, students are assigned, "list some of the ways that humans have influenced the environment". As cited earlier, *Table 6.2* provides a contextual profile of these lessons. *Of note, the participant offering students advice on anticipating problems is based on the lesson observation; this is unexplained in interviews.

As activities shift from structured to open inquiry, Jack suggests this raises opportunities for student learning. But this comes with a trade-off: "It's just harder to monitor [learning]". Jack sheds light on his 'most open inquiry' lesson. In this activity, students complete an independent project. In the final interview, though, after synthesising student work, Jack explains, "I couldn't make sure they were all learning to the same degree". On the next page, *Table 6.4* depicts his dilemma.

Table 6.4. An Event of Independent Activity and Imbalance of Student Learning

Person	Response
Participant	Some of them pursued lines of inquiry that I personally don't think were particularly relevant for the curriculum. So, some of them went… talking about natural selection… but it is part of the natural selection of speciation topic that was already covered… For them, that was quite a safe thing to talk about. Because I already taught it and they already knew it. Whereas the ones who chose to pursue how the atmosphere had changed and how pollution levels in oceans would drop and global warming would slow down and these kinds of things, that was new to them, it was new information and it was on topic and it was relevant. So, some of them… ended up getting more out of it than others.

Source: Transcript (Final Interview, 2 May 2015, p. 11).

In the table above, Jack appears to see some students stretching to learn new things; for others, however, it was "helpful as a revision process". He states: "without structure... you get this accidental imbalance of knowledge". He distinguishes learning that is new versus already known to students. Because of this, he adds, "[it] would be difficult then to put together a mark scheme". Interestingly, this might be an assumption he makes with his classification of 'most open inquiry'. In an interview, he explains this work gives students "total freedom" to pursue the question. But from analysing artefact slides and observation notes, Jack makes three requests: that students think about the atmosphere, landscape and organisms; use reliable sources; and limit the project to three pages. To support a mark scheme, Jack could have added a student request: aim to answer the question based on topics not tackled. Though, as a counter argument, it could be that students interpret Jack's definition of requests as freedom.

6.2.2. Explore Topic and Reveal Misconceptions

Along with independent activity, the analysis suggests another theme. Jack views inquiry as a way for students to explore topics and for teachers to tease out misconceptions that, he suggests, are "problems with [student] research". In an interview, he cites an event of confusion in a chemistry lesson. On the next page, *Table 6.5* illustrates this.

Table 6.5. An Event of Exploring Topic and Revealing Misconceptions

Person	Response
Participant	[The students and I] were talking [today] about acids and alkali. And indicators and the idea of neutral solution and I wanted them to explore it themselves completely. And there were some small groups who got very confused to the point of even confusing the word alkali and alcohol. And they started… talking about, oh, is that why drinks are different colours[?] And is that why alcohol makes you drunk and it all got very, very confusing. And so when I was talking about the acids and alkali thing, this confusion between alkali and alcohol, there's no way I would have ever guessed that was going to be a confusion but it seems to be with this particular class. They're really hung up on that so I need to approach that. But in doing a big inquiry lesson in lesson 1, I figured it out early so hopefully I could fix it.

Source: Transcript (First Interview, 13 March 2015, pp. 1-3). Of note, this lesson was not observed. Jack comments on an inquiry lesson he had practiced the day I had started the first interview.

In this table, Jack captures student misconceptions with acids, alkali, and alcohol. With young students, he suggests the exploratory-and-misconception approach could fix problems early. He also explains this applicable later in lessons: "with older students… I tend to use it towards the end of topic as a kind of summarising, revision, contextualising task to try to make it more interesting and [to] try to figure out any tiny problems with the topic". He adds, "But that's purely to avoid me making mistakes on their GCSE or A-Level preparation. So it's a bit of a protection". In this way, Jack appears to proactively learn about student misconceptions. To this end, Jack seems to view inquiry as a way to prepare for exams with older students and to tease out problems with young students.

Whilst exploring topics, Jack avoids inquiry if he expects many misconceptions. Amongst the lessons observed and physics vignette presented, he notes an absence of misconceptions; but, with a biology vignette presented, he predicts problems. He explains: "there would be a heck of a lot of misconceptions" because of the complex topics with "lots of cognitive leaps… to make everything fit together". He seems to see this as 'broad' inquiry. He suggests 'broad' inquiry corresponding to topic complexity. To avoid this, he would "[give students] some non-inquiry lessons first, [to] be quite confident with their knowledge and then let them explore". Here, he bounds student exploration. Interestingly, with this rationale, it could be that this vignette is unique because of the multiple science topics. Amongst other reasons, it might be the peculiarity of Jack's experience with students and their engagement with topics.

6.2. Factors Promoting Inquiry

This section turns to the second research question: factors influencing inquiry. In particular, one theme is laid out. Jack reflects on student knowledge and behaviour as promoting inquiry.

6.2.1. Student Knowledge and Behaviour

In both interviews, Jack reflects on the benefits of student knowledge and behaviour when using inquiry. He cites an example when students investigate the impact of human extinction on Earth. In particular, he notes: "they are very good at…filtering information on the internet, and so they know what to trust". As a reason, he adds, "train[ing] them and other teachers have trained them… to really identify reliable sources and how to work independently".

Along with knowledge, Jack points to the benefits of student behaviour. In one lesson, where students extract DNA from kiwi fruits, he adds, "the behaviour of the class… there's a camaraderie amongst them where they really don't mind if they're wrong or right. So I think that helps a lot with inquiry". Interestingly, in this lesson he seems to omit student knowledge. It could be that he drew more on behaviour as a driver for inquiry; or, it might be due to different reasons, such as Jack assuming knowledge present and needing good behaviour. Likewise, in a lesson studying the effect of temperature on cell membranes, Jack suggests confident behaviour amongst students. He explains, "It felt like quite a nice atmosphere in there… kind of a[n] experimental buzz". Again, he appears to focus on student behaviour rather than knowledge. This could be due to the nature of work since, according to observation notes, the task involved students following a set of steps that might require little knowledge. Alternatively, Jack might be assuming students have the needed knowledge.

Like the lessons observed, Jack seems to stress the need of knowledge and behaviour when reflecting on the vignettes. He suggests the biology vignette as 'broad' inquiry because of complexity. Accordingly, he suggests building knowledge by engaging students with "some non-inquiry lessons first". With the physics vignette, he points to behaviour. He notes teachers, first, need to show students why the activity is interesting; as an example, he adds, "[ownership] makes it engaging". To this end, for one vignette Jack appears to emphasise knowledge whilst for another he focuses on behaviour.

6.3. Factors Constraining Inquiry

Now I extend the previous section by noting two themes that constrain inquiry. I begin with school resources. And then, I turn to a drive to show measurable attainment.

6.3.1. School Resources

In interviews, Jack suggests school resources of time and equipment constraining inquiry. To illustrate this, in the DNA lesson Jack signals his students: "My only request is that we use reasonable and appropriate amounts of liquids. This is all the equipment we got". In an interview, he explains, "[with that lesson] it would have been nice to have given them a range of different ways… But we are in a state secondary school, and the equipment is limited". Likewise, in the biology vignette presented, Jack suggests the constraint of equipment. He adds: "it would be fantastic to have mice versus fish versus insects… but clearly in a secondary school it's just impossible".

Along with equipment, Jack notes the resource of time: "[in the DNA lesson] there were exams… so I really couldn't waste time doing a big long project". In another lesson, he echoes the tension of time: "[in the effect of human extinction on Earth] we could have just kept going and kept exploring… I can't justify teaching something off curriculum for long periods of time because actually their exams will also suffer". Jack suggests time once again with the biology vignette: "it would be lots of teacher work, lots of planning".

Interestingly, there are two instances where Jack omits discussing school resources. With the lesson on the effect of temperature on cell membranes, students were asked to follow directions for their practical work. In this lesson, it might be that his school equipment was available. Along with that, it could be that time was suitable for this lesson since it was a practical and limitations had been imposed. Similarly, with the physics vignette presented, he explains, "everything you need is there… they've got these ten lessons to do it. So there is plenty of time". However, this reasoning contrasts with the previous paragraph rationale. In that paragraph, he explains the lesson on human extinction and cites time as a constraint due to the length of three classes. Yet, the physics vignette would take 10 classes. This discrepancy could be due to differences in the lesson content in which one is more relevant than another, for instance, with exam preparation. As a counter argument, it might be that there are interacting factors such as Jack's personal preference in teaching the physics vignette and his curriculum needs.

Whilst resources are constraints for Jack, he also notes the benefits of having good quality and abundant resources. Referencing past experience with inquiry work, he explains, "[students had] laptops and leaflets, posters and textbooks from different periods of time and from different areas in different countries". Without resources, he suggests students would have been "stuck within the parameters of the [single] textbook".

6.3.2. Drive to Show Measurable Attainment

Jack also suggests a drive to measurable attainment constraining inquiry. In an interview, he seems to see inquiry raising fears for school management. Unlike traditional teaching, he suggests management may view inquiry as adversely impacting student attainment. On the next page, *Table 6.6* illustrates this.

Table 6.6. An Event of School Perspectives on Achievement

Person	Response
Participant	I think there's a really fundamental idea in education that students should be achieving in measurable exam based manner and I think that makes people a bit fearful of inquiry. And I really think, that's the main thing, you know, in terms of resources and money and funding and time for planning and all those other things would be second to the fact that actually we're just trying to get these guys Cs at GCSEs [General Certificate of Secondary Education] and then get them to university through A-levels. And I think that's what it comes down to from the school's point of view.
Interviewer	C's at GCSE's?
Participant	Yeah, so a C grade, the kind of magic grade for a head teacher, for a school and for your national performance is as many students as possible getting C or above at GCSE. Anything below a C is considered a fail essentially. And so anything that would, could risk a student falling below a C. For example, spending every lesson just exploring things in a[n] unstructured way, that's to be avoided.

Source: Transcript (First Interview, 13 March 2015, pp. 12-13). Of note, GCSE is a qualification awarded in subjects, including Science.

In this table, Jack seems to explain administrators' hesitance in unstructured activities. Nonetheless, these views are based on his perceptions of school management. In other words, the views could differ from the school or head teacher's stance. For instance, it might be that officials would welcome inquiry instruction regardless of its influence on student grades. Alternatively, it might be that schools may encourage teachers to use inquiry for reasons other than grades, such as development of student confidence.

Along with school perspectives, Jack draws on his personal views on attainment. In the final interview, he discusses the lesson on human extinction. He suggests placing limits on the length of lessons to three classes since "their A-Level places [may] suffer". He seems to justify this since the lesson could get "off the curriculum". With this explanation, he appears to omit looking at this the other way. For instance, an inquiry lesson like the physics vignette staying on curriculum and tackling more content and the implications of this.

This chapter presented the findings of the formal study. Five themes emerged. Two themes focused on the views and understandings of the exemplary secondary science teacher on inquiry. Then, three themes described the factors promoting and constraining inquiry for the teacher. I now discuss this data with the literature in England and the USA.

7. DISCUSSION

In this chapter, I trace the findings back to the literature and critically examine the results. I begin this discussion by exploring the views and understandings on inquiry. Next, I turn to the factors that promote and constrain the use of inquiry.

7.1. Views and Understandings on Inquiry

Jack suggests inquiry instruction is an activity that students pursue independently. He discusses and demonstrates lesson activities in which students plan methods, use equipment, and examine sources for investigative purposes. Interestingly, his descriptions of activities and skills match the established definitions of inquiry by Crawford (2014) and the National Research Council (1996), respectively. However, there is one difference: the term 'independent' is absent in these definitions. Comparing this to the literature review, seven of the eight studies in England and the USA also omit noting independent activity. Only Ofsted (2013) suggests inspectors seeming to observe inquiry when students pursue independent activities; yet, this report fails to define the terms inquiry and independent.

Drawing on Jack's observations, he seems to be a bystander for two lessons—the impact of human extinction on Earth and the effect of temperature on cell membranes—whilst students engage independently in activities. However, in his third lesson—extracting DNA from kiwi cells—he does walk around to get involved with students. In this way, the point of students working independently seems different from his previous two lessons. This could be Jack's approach to independent activities. Still, this seems to challenge the idea of students pursuing an activity independent from the teacher. It would have been useful to ask Jack about this independence alteration. On the one hand, this raises the question if independence between teacher and student could be flexible. On the other hand, if I had conducted more observations, it would have been insightful to see if he continued to be flexible with independence and why. Whilst Ofsted (2013) failed to mention the nature of independent activities in their report, it would be interesting to see if, in future reports, they observe teachers practicing activities independently in different manners. To this end, there could be layers of independence with inquiry that might merit attention.

Along with independent activities, another notable feature is Jack's language. He uses 'structured' and 'open' to describe activities. And he seems to begin each activity by offering students a prompt or question. However, in previous literature (Crawford, 2014; Schwab, 1962), this approach would be classified as 'structured' and 'guided'. In contrast, 'open' inquiry tends to be activities where the students pose the question and also come up with ways to solve the problem; using this definition, 'open' inquiry was absent in Jack's lessons. This nuance could be due to peculiarities of his interpretation of inquiry. For instance, whilst discussing a biology vignette, he also articulates a novel term, 'broad' inquiry. He explains this based on topic complexity. Interestingly, this notion of topic complexity and its relationship to inquiry seems absent in the literature. Topic complexity with instruction might be an interesting way to add dimension to communicate about inquiry.

Whilst engaging in independent activities, Jack's lesson topics focused on biology. He began inquiry by offering students a prompt or question, and they carried out investigations. Interestingly, Breslyn and McGinnis (2012) also report a similar pattern on biology when asking exemplary teachers in the USA about their views on inquiry. Although, when presenting the biology vignette, Jack mentioned he would first make sure students understand the topics. And then he noted to introduce "a biological process"; here, it was unclear if he would have followed the pattern. It would have been useful to ask him how he would begin and end this work. This also raises an interesting question if more teachers in England might also practice in this manner and the implications of this. If so, then inquiry lessons could be efficiently designed to support teachers.

Another theme in this study was Jack viewing inquiry as a way for students to explore topics and for him to reveal misconceptions. He proactively used inquiry. For instance, with older students he suggested practicing exploration and misconception to help his students contextualise and see the work as being interesting. He also learned about students' problems by topic to help them prepare for exams. In contrast, Ofsted (2013) claims teachers who instruct older students would engage in “atomistic” instruction, that is, so students learn skills for GCSE (p. 36). This could be similar to formative assessment (Harrison, 2014; Zuiker and Whitaker, 2014); in these studies, teachers seemed to use models or listen during student discussions to find student errors. Interestingly, Jack seemed to go beyond this by using it to help students see the big picture whilst preparing for tests. As pressure mounts to prepare students for high-stakes science tests (Olson *et al*., 2015), the idea of using inquiry for exploration and finding misconceptions holistically could be useful and might be an avenue for future research. Teachers could ask: How useful is it to let students explore a question, so that I may use this time to learn about their misconceptions?

7.2. Factors Promoting Inquiry

Consistent with some studies, Jack notes student knowledge and behaviour as factors promoting inquiry (Crawford, 2007; Roehrig and Luft, 2004). With knowledge, Jack suggests his students were trained not only to use reliable sources but also to work independently. In this way, he suggests students had tangible knowledge to use whilst engaging in inquiry. Somewhat similarly, Roehrig and Luft (2004) studied novice USA teachers and found teacher perception of student ability as a factor promoting inquiry rather than actual knowledge. Teacher perception is interesting. For Jack, perception of student ability was important when he used inquiry to explore topics and reveal misconceptions. If he expected students to have many misconceptions, then he suggested avoiding inquiry to focus on traditional lessons to foster student knowledge. In this way, Jack’s perception of student ability and his knowledge of their student ability both seem to be important prior to engaging in inquiry instruction. Although, as a counter argument, it could be that Jack might be focused less on his perception of student ability and more on generally instilling student knowledge so any student could engage with inquiry. For instance, in the biology vignette presented, he remarked about the complexity of the topic. Yet, absent in his discussion was “giving up” on students. Instead, he mentioned to build up student knowledge with traditional lessons prior to engaging in inquiry.

With respect to behaviour, Jack reflected on the importance of student camaraderie and engagement to promote inquiry. Interestingly, Crawford (2007) seemed to suggest poor behaviour led to student resistance that constrained inquiry. In that work, USA novice teachers explained students were disengaged with inquiry instruction. In particular, these teachers pointed that students wanted directions and certainty with answers. And these students' views were not taken into consideration. In contrast, Jack appeared to first consider students' views to promote inquiry. For instance, when presented with the physics vignette, Jack referenced the importance of getting students to recognise that they have ownership of the work. To this end, students may get motivated and engage with inquiry. Asking students about their views was beyond scope of this study, but it may be interesting for future researchers to investigate the relationship between student motivation and inquiry instruction.

7.3. Factors Constraining Inquiry

In this study, Jack suggested time, equipment, and a drive for measurable attainment constraining the use of inquiry. He cited time needed to plan lessons and the tension with spending time with topics outside of the curriculum constraining the use of inquiry instruction. In previous research, time was also noted to influence inquiry (Ofsted, 2013). Interestingly, Ofsted inspectors reported that some teachers took advantage of time by limiting content taught. Inspectors observed such teachers aiming to instruct limited content rather than all the content in the curriculum for students to engage in inquiry. However, in their report, Ofsted omits discussing contextual factors related to these teachers. For instance, it could be that these teachers come from schools with freedom to instruct limited content. Comparing this point to Jack, he might have come from a school where it would be required to teach all content because of school management. Indeed, in an interview, he points to his perception of school leadership aiming to avoid teaching in an unstructured way. This could imply that he has limited freedom. As a counter argument, Jack's school might have allowed him and others content freedom if he asked. To this end, capturing details about the role of contextual factors in the school would have been insightful. Indeed, Ofsted (2013) has reported that school leadership may play a role to foster a mission that promotes activities of student independence. Asking school administrators, and reviewing their policies on teaching freedom, might be an area for future research.

Along with time, Jack mentioned the resource of equipment as a constraint. He suggested limited supplies in the context of his current school environment. Somewhat analogous, Engeln *et al*. (2013) found math and science teachers using inquiry in England reporting the constraint of systemic restrictions. However, these investigators failed to describe the meaning of systemic restrictions; on the macro level, it might be school or policy related constraints related to inquiry. Amongst other things, on the micro level, it could indeed be equipment. Interestingly, Jack also mentions the benefits of having abundant resources from his previous teaching experience. In this way, his constraint for inquiry seems to be dependent on his circumstances.

Finally, Jack suggested the constraint of drive to show measurable attainment. Interestingly, this view is absent in the literature. He seemed to suggest a tension between using inquiry instruction and its impact on student attainment. In particular, he cited his perception of school administrator reaction if he used inquiry. In this way, evidence from his school leadership may have been insightful to review. As noted above in the paragraph on time constraints, Ofsted (2013) cited that in some schools, leadership made it a mission to foster independent learning. Nonetheless, like England, the USA also has a strong accountability system. To this end, asking teachers and leadership in the USA about their stance on the relationship between inquiry and student attainment might be an idea to consider as inquiry and its goals for learning are clarified in the USA.

7.4. Conclusions

To my knowledge, this is the first in-depth case study on inquiry instruction in England. This research is based on a sample size of one teacher and, as such, it may be improper to transfer or generalise findings from this work. Nonetheless, the study does offer some new considerations. First, the descriptions in the findings itself might be useful to secondary science teachers in the USA to read in the context of a curriculum akin to a framework being set up in America. Jack's use of inquiry instruction in the three lessons observed, his feedback from the two vignettes presented, and his sharing of artefacts might offer teachers alternative perspectives and vicariously anticipate issues whilst instructing inquiry. For instance, from the findings, the figure constructed describing the three types of inquiry practiced could serve as an illustration; teachers may consider differences in interpretation as he explains the strand of How Science Works in the National Curriculum in England to prepare students for independent activities.

Second, Jack's approach of exhibiting independent activities, from acting as a bystander to engaging with students, and his idea of topic complexity or 'broad' inquiry might be worth considering; these differentiations seem to be absent in the literature and could be useful elements to simplify the thinking around inquiry instruction. And third, as teachers in the USA convene to clarify the meaning of inquiry, it might be helpful to consider inquiry instruction not only as a way to foster independent student activities but possibly as a utility for teachers to reveal student misconceptions.

Along with views and understandings, Jack also reflected on factors that promote and constrain inquiry. He reflected on student knowledge and behaviour as factors promoting inquiry whilst school resources and a drive for measurable attainment constraining inquiry. On the one hand, like teachers instructing in different environments, these factors may be contextually dependent. On the other hand, his justification of why they influenced his inquiry instruction might be useful to think about.

8. LIMITATIONS, CONTRIBUTIONS, AND REFLECTIONS

In this chapter, I close with limitations and key takeaways. Whilst aspiring to research inquiry, I recognise that this work has several limitations. First, the sample size is limited to one participant. Since this is qualitative work, there may be peculiarity and specificity with the atypical case. This was anticipated, though. The aim of this research was to not to generalise to teachers in England but to attain richness in heuristic value by asking the skilled teacher. Also, I chose a trade-off. I carried out the formal study with the atypical skilled teacher over multiple typical teachers. Instead of gaining general knowledge of inquiry in England as attempted by Ofsted (2013), I intended to capture nuanced understanding of the complex factors influencing inquiry instruction (Gilbert, 2011) in England, since, to date, there has been a gap in the literature.

Another limitation is the reductionist approach to this work. Unlike statistics, qualitative research tends to analyse copious data to generate themes. Inevitably, by definition this leaves out every word. Still, the benefit of themes is to structure and transmit information on inquiry in a clear way to generate new knowledge for the field (Lichtman, 2013). Credibility is paramount for such work. To this end, I aimed for validity by using an audit trail, data triangulation, categorisation checking with an experienced qualitative researcher, and response validation for the themes and organisation.

A third limitation is the practice of considering ideas from one nation for another. By designing a study in England, I hoped to gain insight on inquiry to contribute to the discussion on clarifying inquiry in the USA. Yet, with such work, I acknowledge scholars arguing that there may be contextual factors influencing the research questions, which may be difficult to identify (Cohen, 2014; Loveless, 2014; Sadler, 1900). In this study, I tried to consider this issue by offering counter and alternative explanations to arguments; yet, like research that is exploratory in nature, it could be that there have been variables that were not been captured.

Given these limitations, this research could contribute some new ideas to the secondary school teacher audience based on the themes of independent activity and use of inquiry as a way to explore topics and reveal misconceptions. The work might also contribute to the scholarly field by offering thick descriptions on points about student knowledge and behaviour promoting inquiry whilst absence of school resources and the drive for attainment constraining inquiry for this teacher. By studying the skilled participant in England, I was impressed by the confidence and clarity in the way he viewed and understood inquiry as well as the way in which he explained building student skills. I also reflected on the various terms the participant used to explain inquiry. Whilst most terms used seemed to be standard in the inquiry literature, the descriptions and explanations somewhat varies with this teacher. These differences have also been observed in the literature (Crawford, 2014; Osborne, 2014) and, to improve the communication of inquiry internationally, this research adds to calls for the profession to establish a common typology of inquiry instruction.

This was a valuable experience for me as I transitioned from teaching and researching in the USA to take time to study inquiry in England. I hope to take these descriptive findings back with me and share them with secondary science teachers and researchers in the USA. It may be useful to think of this work as the community embarks on finding ways to standardise the meaning of inquiry instruction. In practice, secondary science teachers in the USA could reflect on reading these findings and anticipate issues with teaching inquiry. Avenues of future research could include replicating this study with the skilled teacher in the USA to ask about their views and understandings on inquiry as the new science framework gets implemented. Then, for the science community, it might be useful to compare and contrast this evidence of views and understandings and ask what, if any, similarities and differences are present and how this evidence can be useful to clarify instructional issues in the pursuit of fostering inquiry skills for students.

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10. APPENDICES

10.A. APPENDIX A: SCHEDULE OF EVENTS

Schedule of Events for the Research on Inquiry Instruction in England

	15-30 JAN	1-15 FEB	16-30 FEB	1-15 MAR	16-30 MAR	1-30 APR	1-30 MAY	1-30 JUN	1-12 JUL
Teacher Contact									
Give Consent									
Pilot Study									
Formal Study									
Data Analysis									
Member Checking									
Thesis Writing									
Thesis Editing									

Source: Author's Interpretation. Of note, with first interview questions and vignette scenario texts, feedback was offered in the Pilot Study prior to engaging in data collection for the Formal Study.

10.B. APPENDIX B: INTERVIEW PROTOCOL OF FIRST SESSION FOR FORMAL STUDY

1. How do you define inquiry instruction?
    i. How do you feel about inquiry instruction as a pedagogical practice?
    ii. At which specific times would you use inquiry instruction?
2. What is your goal for inquiry instruction?
    a. "What do you want students to learn?"
    b. "How will you know what students are learning?"
    c. "How will you respond when they do not learn?" (National Research Council, 2013, p. 135).[xxii]
3. What are your views and understandings on inquiry instruction?
4. What factors support your use of inquiry instruction?
    i. How do you feel about the number of students as a factor?
    a. What types of curriculum materials are used for inquiry?
    b. How are time and resources allocated for inquiry?
    ii. How do you feel about policies around inquiry instruction?
    c. What policies support your use of inquiry?
5. What factors constrain your use of inquiry instruction?
    a. What policies constrain your use of inquiry?
    i. Are there staffing issues that constrain the use of inquiry instruction? Do you need extra staff to watch students?
6. Do you think the National Curriculum has an influence on the way you use inquiry instruction?
7. If you were the researcher, what question would you ask to secondary science teachers about inquiry instruction?
    a. How would you improve the use of inquiry instruction?

[xxii] The three sub-questions were adapted and modified from Appendix K of the National Research Council, 2013, *Next Generation Science Standards: For States, By States*, Washington, DC: The National Academies Press. These queries asked secondary science teachers in the USA to reflect on learning as standards were added in states. Queries were framed as "we"; for the interview, they were modified to "you".

10.C. APPENDIX C: UNSTRUCTURED OBSERVATION DOCUMENT

Background Information
Grade level:
Date of observation:
Start time:
End time:

Context
Number of male students:
Number of female students:
Additional information:

Time	Event

10.D. APPENDIX D: INTERVIEW PROTOCOL OF FINAL SESSION FOR FORMAL STUDY

Introduction

Please note that this is the final interview. This part is split into three sections. The first section asks about the three classes you kindly let me observe. The second section is about two vignettes from a USA context. And the last section asks about background questions on inquiry.

1. Let's talk about the three science inquiry lessons I observed. The first class extracted DNA from kiwi fruits. The second class investigated the effect of temperature on cell membranes. Finally, the last class examined the impact of human extinction on Earth; and when this class ended, students were in the process of preparing presentations to explain their ideas.

For each lesson, I'll ask:

a. What are your views and understandings on this class's inquiry instruction?
    i. What do you think went well?
    ii. What do you think didn't go so well?

b. What factors promoted and constrained your use of inquiry instruction?
c. How do you think this class's inquiry instruction influenced student learning?

Vignettes

I will read two hypothetical vignettes from a USA context. And I will ask your views, understandings, and factors related to them.

2. Mr Sand is doing a biology lesson for 9th grade students to help them learn that behaviour is a trait that is shaped by both genes and the environment. In England, this would relate to Key Stage 4 students engaging with the biology content of "how the genome, and its interaction with the environment, influence[s] the development of the phenotype of an organism" (National Curriculum, 2014, p. 9). This lesson would take about 1 to 2 classroom sessions that are 50 minutes each. With this work, students would confront their prior knowledge on behaviour and its relationship to genetics and the environment based on scientific papers; these students would construct models demonstrating behaviour is controlled by genes and the environment. Students would then collect biology data to make hypotheses and predictions to link concepts of genes and environment of behaviour functions and evolution.

a. Thinking about how you would teach this lesson in England, what are your views and understandings about it and its relationship to inquiry?
b. How do you think this may influence student learning?
c. What factors may promote the use of inquiry?
d. What factors may constrain the use of inquiry?

3. Ms Williams is preparing a physics lesson for 9th grade students to detect extrasolar planets or “planets that orbit stars similar to our own Sun” (Harvard-Smithsonian Center for Astrophysics, 2015, p. 4). In England, this would relate to Key Stage 4 students engaging with the content of “space physics” (National Curriculum, 2014, pgs. 16-17). This lesson would take about 5 to 10 classroom sessions that are 45 minutes each. Since current telescopes can rarely see extrasolar planets directly, an indirect method would be used called “planetary transit”. With this work, students would use a web-based telescope [*personal note: show the lesson plan which describes this*] to collect data by taking images of a target star to look for a dimming of starlight. Students see the dim when an exoplanet passes in front of a star and eclipses the light for a short time. During this time, students would measure the brightness of a star and graph it over time to see the dip. Like scientists, students engage with the “messiness of real data” and analytical work “to separate the signal from the noise in their investigations” (Harvard-Smithsonian Center for Astrophysics, 2015, p. 3).

a. Thinking about how you would teach this lesson in England, what are your views and understandings about it and its relationship to inquiry?
b. How do you think this may influence student learning?
c. What factors may promote the use of inquiry?
d. What factors may constrain the use of inquiry?

<u>Background Information</u>

4. How did you learn about inquiry instruction? (Probe: from education, professional development, and/or prior science career?)

5. What do you think makes you skilled and highly qualified at using inquiry instruction?

6. Do you have any questions or comments?

10.E. APPENDIX E: DESCRIPTIVE PILOT FINDINGS

The purpose of the pilot study was to develop data collection tools for the formal study. In particular, this helped refine the text of the interview questions and vignettes for the formal study. Key lessons learned in making changes to texts are discussed in the section, *Data Collection*. Another lesson learned was that conducting interviews in a coffee shop was fairly noisy; accordingly, it was useful to carry out interviews in a quiet place. The pilot participant was female, with teaching experience of four years, instructing at an independent school [redacted] with PGCE [redacted] The external artefact analysis showed materials focusing on areas of content coverage, learning outcomes, activities and resources. The content focused on chemistry. Yet, there was an absence of reference to inquiry. The internal artefact analysis presented an inquiry lesson of the heart for students to dissect and communicate findings.

In the following, I share descriptive findings learned from this teacher. This data is generated from the unrefined tools; accordingly, it might be inappropriate to compare the results with the formal study (Yin, 2014), as text wording for questions may have been different. Nonetheless, the descriptive findings were response validated:

"I'm happy with the layout and after having read the section you wrote, I'm happy with the content for that". Source: Author's email (Pilot Study Participant, personal communication, July 9, 2015). These are the findings:

The pilot participant views inquiry instruction as a way for students to find things out by themselves, and to learn more and achieve good grades. For the participant, inquiry is a way for students to construct their own knowledge through a variety of different skills. This is important for the participant since inquiry may prepare students not only for exams but also for life beyond school.

For the pilot participant, there are several factors that may 'support' inquiry. (Of note, in the formal study, this was changed to 'promote'.) First, the participant supports herself by doing research in her own time. Second, the participant will collaborate with colleagues, having training sessions in class and Continuing Professional Development (CPD). Third, the participant is supported by Bloom's Taxonomy. And fourth, the participant gets support from the National Curriculum topics as it gives opportunities to build inquiry lessons.

In terms of constraining factors for inquiry instruction, the participant says time, parents, and students.

With the physics vignette (i.e. extrasolar planet), the pilot participant commented that students would be doing the work and it would be a nice step towards A-level and university. As a constraint, the participant mentioned it would take a long time.

With the biology vignette (i.e. behaviour), the pilot participant commented about a documentary she saw about making up a scenario and posing it to the students. This would develop scope for the work. With constraints, the participant mentioned making sure it links with the work and prior experience with inquiry.

10.F. APPENDIX F: EXAMPLE OF INTERVIEW AND VIGNETTE ANALYSIS FOR THE FORMAL STUDY

Example of First and Second Stage Analysis to find Category: Search for Repetition

Verbatim Interview Text Highlighted text notes searching for repetitions	Category
First Interview on 13 March 2015 (Transcript, p. 1)	
Interviewer: How do you define inquiry? *Participant:* Right, I think personally, inquiry is any activity or task where the students are expected to pursue something independently. So there might be different degrees of structure. But it has to be something that they do themselves. They have to have some independent work where they're not just being spoon-fed, if you like, information from the teacher. It's more a kind of process where they investigate things and they work things out. Yeah, but I think that's the essence of it for me.	Pursue Something Independent
Final Interview on 2 May 2015 (Transcript, pp. 6-7)	
Interviewer: What are your views and understandings on this class's [the effect of temperature on cell membranes] inquiry instruction? *Participant*: That was the Year 12. That was the older students. That was much more structured, much more structured I think. It was a full set, there was a method that they had to follow and that was for an assessment wasn't it? It was a method that they had to follow rigidly. There were observations that they had to, they had to get their correct observations in order to get their marks on the paper. Now they didn't know if there were seeing the right thing or not. And I think the thing that made that inquiry is there was, they were working independently and there was no input from me whatsoever. So they were really on their own.	Working independently
Vignette on 2 May 2015 (Transcript, pp. 20-21)	
Interviewer: Thinking about how you would teach this lesson [vignette on behaviour] in England, what are your views and understandings about it and its relationship to inquiry? *Participant:* I think they could be very inquiry based but behaviour and genetics and learning and inheritance is very complicated. There's lots of cognitive leaps you have to make, and you have to have a real understanding of biology and the environment, and learning, to make everything fit together so you'd have to be confident that your students could work within that topic independently. So I definitely think about, before I attempted the inquiry lesson, I'd do a series of lessons building up their knowledge. And then let them go with an independent task.	Work within that topic Independently; Independent Task

*In the text analysis, I searched for repetition across interview and vignette responses. Through data triangulation, this participant viewed and understood inquiry as a chance for students to pursue something independently. The category—independent—emerged from the data frequently; it also became one of the themes for the first research question.

10.G. APPENDIX G: FINAL CATEGORY SCHEME FOR THEMES

Final Category Scheme for the Research on Inquiry Instruction in England		
Research Objective	Final Category	Theme
Views and Understandings on Inquiry	▪ Pursue something independently ▪ Develop students' scientific skills (i.e. experimenting, investigating, trial and error), repeating things, and discussing things for independent activity ▪ Develop confidence for independent activity ▪ How Science Works for independent activity	Independent Activity
	▪ Younger vs. older students exploring a topic and revealing misconceptions for inquiry ▪ Complex topic exploration may generate many misconceptions, based on a vignette classified as 'broad' inquiry vs. Simpler topic, based on lessons observed and one vignette presented, may have absent of misconceptions; these lessons were classified as 'structured' and 'open' inquiry	Explore Topic and Reveal Misconceptions
Factors Promoting Inquiry	▪ Student Knowledge (e.g. use of reliable resources, having academic tools) promotes inquiry lessons ▪ Behaviour of Students promotes work with inquiry lessons	Student Knowledge and Behaviour
Factors Constraining Inquiry	▪ Time in the School ▪ Equipment (i.e. biological, chemical, material) in the School	School Resources
	▪ Teacher perception of school's point of view of drive to show measurable attainment ▪ If inquiry is used, exams will suffer with drive to show measurable attainment	Drive to Show Measurable Attainment

10.H. APPENDIX H: EXAMPLE OF OBSERVATION ANALYSIS FOR THE FORMAL STUDY

Example of Third Stage Analysis to Compare and Contrast Data from Category

<table>
<tr><th>Time</th><th>Verbatim Event
Highlighted text illustrates patterns</th><th>Notes on Patterns
Italics text showcases analysis</th></tr>
<tr><td colspan="3">An example from the lesson: Extracting DNA with Kiwi Fruit (i.e. 60 minutes)</td></tr>
<tr><td>9:24 am</td><td>Participant (P): Think about why you're doing each thing.
P asks one group: Why are you doing [this]? Why?</td><td rowspan="3">At the beginning and middle of this 'partially structured' inquiry lesson, the participant seems to raise common questions: "Why?" and "Why are you doing this?" This is whilst students work independently in groups.

This seems to corroborate the interview: "you can walk around and get involved and get them to use the right words" (First Interview Transcript, 13 March 2015, p. 5).

At the end of this lesson, the participant asks, "What's the point?" "What else?" "What is that called?" A majority, if not all, students appear to engage with the participant.

This appears to support the interview: "at the end that really assesses how they've develop through the lesson" (First Interview Transcript, 13 March 2015, p. 4).</td></tr>
<tr><td>9:36 am</td><td>Student (S): We flooded it with salt first. Crushed it all up. Then we added more salt. Then we put the liquid in.
P: Why? What's there?</td></tr>
<tr><td>9:56 am</td><td>P: What's the point?
P: What's the point of washing up liquid?
S: Breaks the cell membrane down.
P: Then water bath, what's the point?
S: Speeds up the reaction.
P: Floating ethanol what was the point?
S: It dissolves…
P: What else?
P: In chemistry, what do we call it, and makes things go cloudy. What is that called?
S: Precipitate.</td></tr>
<tr><td colspan="3">An example from the lesson: Effect of Temperature on Cell Membrane (i.e. 100 minutes; 40 minutes lesson review, and 60 minutes practical assessment)</td></tr>
<tr><td>11:26 am</td><td>P: I would say follow the steps… Please, please, read through the whole method before you stop. Read through all.</td><td rowspan="3">At the beginning and middle of this 'much more structured' inquiry lesson, the participant appears to do two things: (1) tell students to follow the steps; and (2) help them think and anticipate patterns.

In contrast, with the interviews, there is an absence in mentioning the support of students.

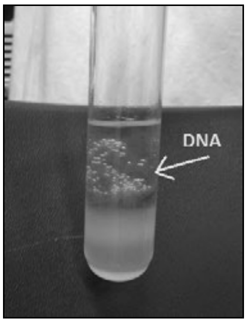
It is similar, though, to the final</td></tr>
<tr><td>11:31 am</td><td>P: What are we expecting to see pattern wise?</td></tr>
<tr><td>11:51 am</td><td>P: My advice is don't go after two decimal places. And don't forget the units.</td></tr>
</table>

		interview: "it was such a rigid structure… they couldn't explore things …" (Final Interview Transcript, 2 May 2015, p. 9).
12:00 pm - 1:01 pm	(The Students are reading the materials. Students are doing their practical by themselves making the solutions and following the procedures.)	At the end, during the assessment part, students appear to work silently and independently. *Similarly, in the interview: "as soon as I said go, they had a set of instructions and they had to do it on their own" (Final Interview Transcript, 2 May 2015, p. 7).*
An example from the lesson: Impact of Human Extinction on Earth (i.e. 60 minutes); this lesson took two more classes in weeks after. I observed the first class.		
9:08 am	(Class starts based on the list Students made on the ways humans have influenced the environment.) S: Pesticides are bad. Because it gets in the food chain. P: Nice, it can get in the food chain. One insect can get poison no big deal, but say a bird eats 10 of those, then it gets 10 times of the poison…	At the beginning of this 'most open' inquiry lesson, the participant seems to engage students with issues of humans influencing the environment to think about the topic of human influence broadly. Once the question is revealed, the participant also appears to encourage students to choose their own approach to answer the question. *This seems to support the participant discussion in the interview: "So, I tend to start with quite a tight structured task for maybe five minutes, ten minutes, at the start of the lesson" (First Interview Transcript, 13 March 2015, p. 4).* *Along with that, the participant encourages students to pursue their approach; the view seems to support the inquiry lesson being 'open': "the most open… all I did… was just ask a question… and then they could approach it however they wanted" (Final Interview Transcript, 2 May 2015, p. 10).*
9:26 am	P: Pursue any route you want with this. P: You have half an hour this lesson. An hour tomorrow. Think about how you want to present this, how you want to pursue this. (Students are reading the materials. Students are browsing the web to see if there are ways to see what to do if the world ends.)	

9:50 am	(One Student is seeing a website, "World without us"); [This is based on a non-fiction book.] (Another two Students used Google to see a website, IFLScience.com.)	At the end of this lesson, students seem to use a variety of resources that are deemed reliable by the participant. *This seems to support the participant interview: "so I've trained them… other teachers have trained them to… identify reliable sources… when I gave them the opportunity, they were really good at it" (Final Interview Transcript, 2 May 2015, p. 14).*
9:52 am	(Last two Students are checking out a website about the documentary.)	

10.I. APPENDIX I: EXAMPLE OF ARTEFACT ANALYSIS FOR THE FORMAL STUDY

Example of Third Stage Analysis to Compare and Contrast Data from Category

Examples of Artefacts from the Lessons Observed	Asking questions: "Who writes them? For what purposes? How are the documents [i.e. artefacts] written?" (Hammersley and Atkinson, 1995, pp. 142-143). Of note, Italics text showcases analysis.
Extracting DNA from Kiwi Cells	
Two sources: Sheet (one page) and PowerPoint (eight slides)	The participant wrote both pieces. With the hardcopy sheet, the purpose is for students to "write a method for extracting the DNA from KIWI cells". This piece was written to give background information. This includes five facts about the KIWI cells, and seven facts about the chemicals and equipment. *Both artefacts compare to the category of independent activity generated from the interview analysis; in particular, the participant cites these instructions for independent activity stating, "so they didn't have a choice of equipment. The equipment was given to them. And they had instructions on what the equipment could do, just not which order to use it in" (Final Interview, May 2, 2015, p. 2).* With the PowerPoint slides, the purpose seems to be first, introduce students to the topic of cells and equipment, and then give them a challenge. Interestingly, all facts in the sheet are displayed in the slides. Then, a visual clue is given on the slide to show what the end of the experiment looks like; that is:  Source: (The formal study participant, personal communication, March 18, 2015). Finally, students are given the challenge: "1. Write a method for extracting DNA from KIWI fruit"; "2. Try out your method (Don't use too much of each chemical"; "3. "Extension – Genetics based exam questions from the GCSE textbook". And once students complete the work, the participant shows the last slide with the solution. *Interestingly, one part of this slide is absent from the category of independent activity generated from the interview analysis. However,*

	it is framed as an extension, and the material seems to be separate from the inquiry lesson as it asks for genetics exam questions in a GCSE textbook. This part is also absent in the observation notes.
Effect of Temperature on Cell Membrane	
One source: Practical (one sheet of a set of instructions)	The OCR wrote this piece. The purpose is for students to "investigate the effect to temperature on cell membranes" using beetroot cells. This document was written to give students a method to follow; students would be assessed on the accuracy of results. Students had to follow 18 steps in total. This is a standardised instruction being used over time across England. Unlike other artefacts for close examination, I was allowed to look at it generally to take notes rather than analyse closely; this is to respect confidentiality. *This artefact compares to the category of independent activity generated from the interview analysis; in particular, the interview supports the use of instruction for the method: "as soon as I said go, they had a set of instructions and they had to do it on their own. So, really that was almost purely skills based. It was just, can they as scientists pick up a method, use the equipment in front of them, and logically read through a method and follow it correctly (Final Interview, May 2, 2015, p. 7.)*
Impact of Human Extinction on the Earth	
One source: PowerPoint (seven slides)	The participant wrote this piece. This is for the purpose of getting students to think of ways humans influence the environment. Also, it is for presenting students a task. At the beginning, the slide opens up with a question: "list some of the ways that humans have influenced the environment". It then points to areas humans have influenced the environment, including the atmosphere, and other organisms. Then the task is unveiled. The slide notes, "Complete an independent research project to answer the question: 'What would happen to the Earth if humans were wiped out overnight' ". Then, a website link to a TED video is offered. *The slides compare to the category of independent activity generated from the interview analysis; that is, to begin the lesson, the uses "a tight structured task for maybe five minutes, ten minutes, at the start of the lesson" (First Interview, March 13, 2015, p. 4).* Finally, the teacher defines independent research: "this is all on you! You can approach the question however you like and use any resources you like". And there are three requests: "think about the atmosphere, the landscape and other organisms", "use reliable sources", and "limit your project to 3 sides of A4 of writing (time is a bit of an issue". Then, the slide notes that it may take more time to do this, including time for homework and for next class; the slides also reminds students to bring in resources for their task for the next class.

	One part of this slide is absent from the category of independent activity generated from the interview analysis. Specifically, the slide makes three requests. In the interview, though, the participant seems to miss discussing these requests made before students embarked on their independent investigation.

10.J. APPENDIX J: INFORMED CONSENT

Informed Consent[xxiii]: Participating in a Study on Inquiry Instruction

What is the Purpose of this Study?
My name is Hardeek H. Shah, and I am a Master of Philosophy student in Educational Research at the University of Cambridge. I am interested in learning about inquiry instruction and the purpose of this study is to review the relationship of inquiry with the views and understandings of the teacher as well as their context. You have been invited because you meet the criteria of interest: exemplary secondary science teacher, who is a leader, motivated to use inquiry, having experience with mentoring colleagues and you have knowledge about inquiry based on your training.

The Process for Data Collection
Information will be collected from 2-3 interviews and classroom observations. Each event will take approximately 60-90 minutes; I will be sure to observe time limits. Also, each event will be arranged at a time and place at your convenience. With interviews, I will ask you to share responses related to inquiry. Questions may ask you to think about your own identity in relation to inquiry experiences. The interviews will be audio-recorded for transcription purposes. With observations, I will aim to take notes on teaching activities, such as inquiry. To contextualise this data, artefacts on inquiry instruction will also be collected; this may include the scheme of work, lesson plan, worksheet, assessment, and/or policy you believe may affect inquiry.

How will the Data be Stored?
Interviews will be transcribed and saved as a text file. Notes from the observations will also be typed and saved as a text file. Importantly, these documents will be password-protected on my computer.

Confidentiality
Please note that my intention is to publish the results of this study. However, your details that could identify you will remain confidential. Pseudonyms will be used in my notes and interview transcriptions to achieve anonymity.

A Right to Opt Out
In this study, participation is voluntary. It is your choice whether or not to participate. You are free to opt out at any time; this will not influence your relationship with me or with the University of Cambridge.

Please turn to the next page.

[xxiii] Parts of the text were adapted and modified from the Sample Consent Form (Committee on the Use of Human Subjects in Research at Harvard University, 2013).

Honoraria
There is an absence of remuneration. But results from this study may offer you insights on teaching as an educational professional.

What are the Potential Risks?
As a participant, there are no known risks or harms. The interviews and observations are exploratory in nature. Please share only what you wish to share. You may decline to answer questions; you may also withdraw from any part of the study.

What are the Potential Benefits?
You may get a chance to reflect on your views and understandings on inquiry, which may be personally meaningful to you. In addition, you may enjoy the sense of helping teachers and researchers learn about inquiry.

Results
After data collection and analysis, I will draft the results. I will also ask you to check these findings to make sure that I have represented your views; please feel free to offer feedback during this time.

Your signature below indicates you have read the information in this consent form, and you give permission to take part in this research.

____________________	____________________	____________________
Printed Name of Participant	Signature of Participant	Date

If you have any questions, my contact information is:

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Thank you.